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MONTHLY BULLETIN

OF THE

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BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION

Note on Train Speeds,

by LIONEL WIENER,
Professor at the University of Brussels.

PART II *(Continued)* [1]

Train speeds and services in different countries.

XVII. — NORWAY.

SUMMARY.

CHAPTER XLVIII.

1. General.
   Track- and loading gauges.
2. Main lines.
3. Isolated lines.
4. Secondary centres.
5. Electric traction.
6. Railcars.
7. Sleeping-car and restaurant-car services.
8. Train speeds.

CHAPTER XLVIII.

XLVIII-1. — **General.** — Norway is a thinly populated country bristling with mountains and cut up by fjords. Consequently high speeds are out of the question, but the railways are interesting, and the train services, worthy of attention.

TRACK- AND LOADING GAUGES (fig. 306). — Out of a total of 3 962 km. (2 689 miles) of railways, 3 584 km. (2 460 miles) are State owned [2], and only 368 km. (229 miles) privately owned.

Far from being uniform, the gauges of the various lines include the following :

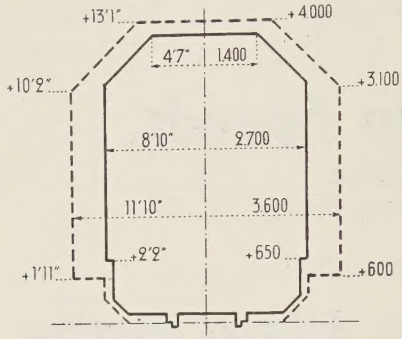
	State.		Companies	
	Km.	Miles.	Km.	Miles.
1.435-m. (4′ 8 1/2″) gauge .	2 823	1 754 2	124 [3]	77.1 [3]
1.067-m. (3′ 6″) gauge . . .	761	472.9	135	83.9
Metre (3′ 3 3/8″) gauge . .	—	—	26	16.2
0.75-m. (2′ 5 1/2″) gauge . .	—	—	83	51.6

[1] Cf. *Bulletin of the Railway Congress*, October and November 1933; January, May, June and July 1934; February, March, April, May, July and October 1935; March, May and June 1936.

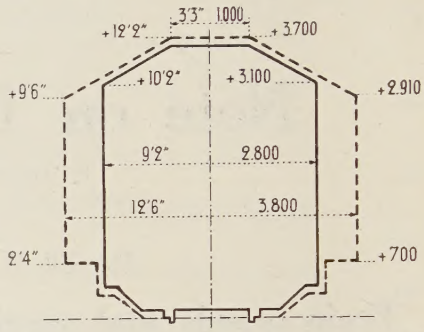
[2] The first section, opened to operation in 1854, was from Christiana to Eidsvoll, and was 68 km. (42.3 miles) long.

[3] The more important line is that of the *Rjukan Ry.*, 16 km. (10 miles) long.

This is an inheritance from the past. In view of the mountainous nature of the country, the 3′ 6″ gauge was first adopted, the construction of lines to this gauge being cheaper than that of standard gauge lines. Elsewhere other railways with no physical connection adopted different gauges, and only later were efforts gradually made to standardise them.



Gauge for standard lines.



Gauge for 3′ 6″ lines.

Fig. 306. — Loading gauges, Norwegian Railways.

But the existence of the original 3′ 6″ gauge caused other complications : alternative lines were built in order to avoid the considerable expenditure involved in altering the gauge.

This explains why there are two main lines between (Oslo) Hamar and Stören (towards Trondheim), one (the western line via Dombas) laid to standard, and the other (the eastern line via Röros), to narrow gauge. In the same way, the original line from Oslo to Brevik via Larvik was built to the 3′6″ gauge, and a new line linking up Drammen with Eidanger (only 9 km. = 5.6 miles from Brevik) via Nordagutu, was built to standard gauge. Like the former, it is exactly 140 km. (87 miles) long, the last section from Eidanger to Brevik being common to both.

Among the works undertaken to relieve unemployment is the widening of the 140 km. (87 miles) of the 3′ 6″ gauge Drammen-Larvik and Eidanger (Brevik) line. This, however, is not the only conversion now in hand. The extension of the *Southern Railway*, now in progress, will link it up with the *Nelaug-Arensdal Railway*, part of which it will use. At the same time the metre gauge is being increased to standard, though the extension itself is being laid to metre gauge.

Apart from the *State Railways*, the following privately-owned railways are the only 3′ 6″ lines still in operation :

Holmestrand-Vittingfoss	30 km. (18.6 miles).
Lier-Starngstrand . .	21 km. (13.0 miles).
Lillesand-Flaksvatn .	17 km. (10.6 miles).
Sulitelma	24 km. (14.9 miles).
Tonsberg-Eidsfoss . .	48 km. (29.8 miles).

As the 264 km. (164 miles) of the Wostfold and Röros lines between Koppang and Stören are being converted to standard gauge, there will remain, by 1940, but 273 km. (169.6 miles) of 3′ 6″ gauge lines, including the 161 km. (100 miles) of the *Flekkefjord-Stavanger Railway*.

The position is the same for the metre

gauge lines, but their evolution is more advanced as only the 26 km. (16.2 miles) of the THAMSHAVN-LOKKEN electric railway are left. The whole of the *Bergen Railway* built to this same gauge, has long ago been converted to standard.

The *Nesttun-Osören Railway* (26 km. = 16.2 miles), and the *Sorumsand-Skulerud Railway* (57 km. = 35.4 miles) make up the 0.75-m. (2′ 5 1/2″) mileage in Norway.

Figure 306 shows the constructional and loading gauges, the overall dimensions of which are as given in table 282.

TABLE 282.

—	Loading gauge.	Constructional gauge.
Standard track	4.20 m. and 3.40 m. (13′ 9 11/32″ and 11′ 2″)	4.80 m. and 3.90 m. (15′ 9″ and 12′ 9 5/32″)
3′ 6″ track	3.55 m. and 2.60 m. (11′ 7 13/16″ and 8′ 6 11/32″)	4.24 m. and 3.80 m. (13′ 11″ and 12′ 5 1/4″)

XLVIII-2. — **Main lines** (fig. 319). — The main lines radiate from Oslo towards the southern ports of Brevik and Kragerö, towards the Atlantic ports of

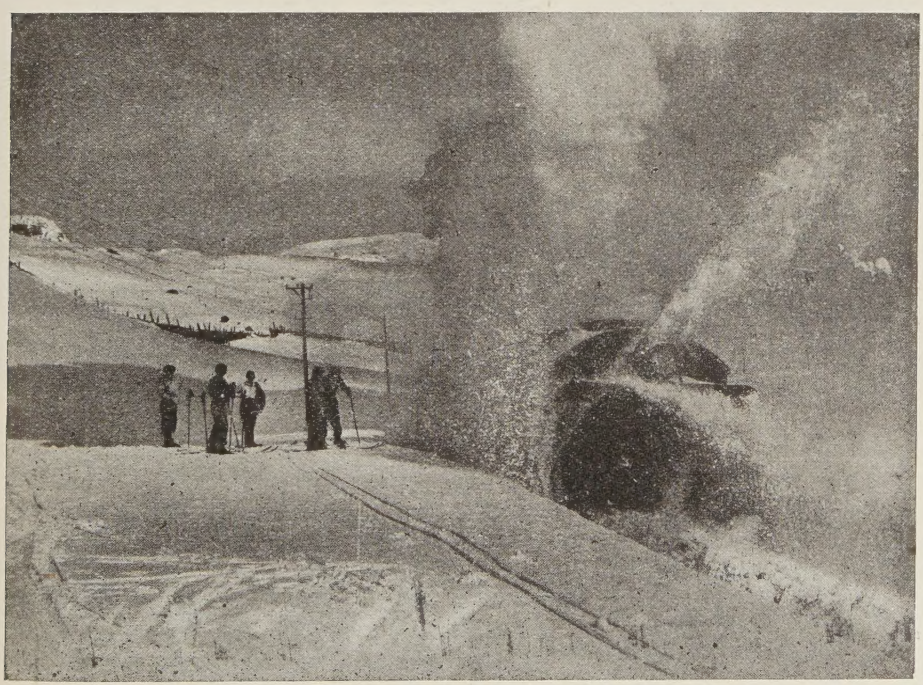


Fig. 307. — Fighting snow on the Bergen Railway.
Rotary snow plough.

Bergen, Aandalsnes, Trondheim and Namsos, and eastward, to Göteborg (via Kornsjö) and Stockholm (via Charlottenberg). A few cross-country lines complete the somewhat loosely laid-out system, and in certain cases, provide alternative routes.

A number of tunnels, including a dozen

Fig. 308. — Snow screens on the Bergen Railway.

over 1 km. (0.6 mile) long have had to be driven (1); more than half of them are on the Bergen Railway.

In southern Norway, the railways do not climb to any great altitudes. Thus, the Brevik railway is never over 332 m. (1 090′) above sea level. The lines linking up Oslo with the Atlantic ports are

(1) Besides those of the *Bergenbanen*, they are the following :

Southern Railway . .	Hjerpehovet.	1 762 m. (1.09 mile).
Rauma Railway . .	Stavem.	1 395 m. (0.86 mile).
Dovre Railway . . .	Hestekrubben.	1 441 m. (0.89 mile).
Flekkefjord Railway .	Ravnejuvet.	1 174 m. (0.73 mile).
	Drangsdal.	2 169 m. (1.35 mile).

therefore the more interesting. Unlike the Baltic ports, these latter, thanks to the influence of the Gulf Stream, are never ice-bound; consequently, the tonnage of goods carried by the railways during the course of the year only shows the usual seasonal variations. On the other hand, they have always had to fight competition by sea particularly to the further North ports and to contend with snow in the Scandinavian Alps. In spite of the many tunnels and the location of the line which, though it climbs up to more than 1 000 m. (3 280′) above sea level, manages to wend its way between peaks more than twice as high, these railways lie for long distances above the vegetation zone which descends very low in these altitudes — 800 m. (2 625′) only in the case of the Dovrefjell.

During the nine-month Winter of this part of the World, snowfalls of 4 m. (13′) are no exception and avalanches are everyday occurrences. All modern methods of keeping the line clear are resorted to : improved rotary snow-ploughs (fig. 307), snow screens (fig. 308) 7 m. (23′) high, in 100 m. (328′) long sections, inclined in accordance with the prevailng winds, like those used in Sudan to protect the track against the desert sand. In Norway, as in Sudan, such screens have proved efficacious, but only for one direction of wind. The snow-screen passage-ways in wood or masonry (fig. 309) are long and are provided with flap-doors which can be opened during fine weather.

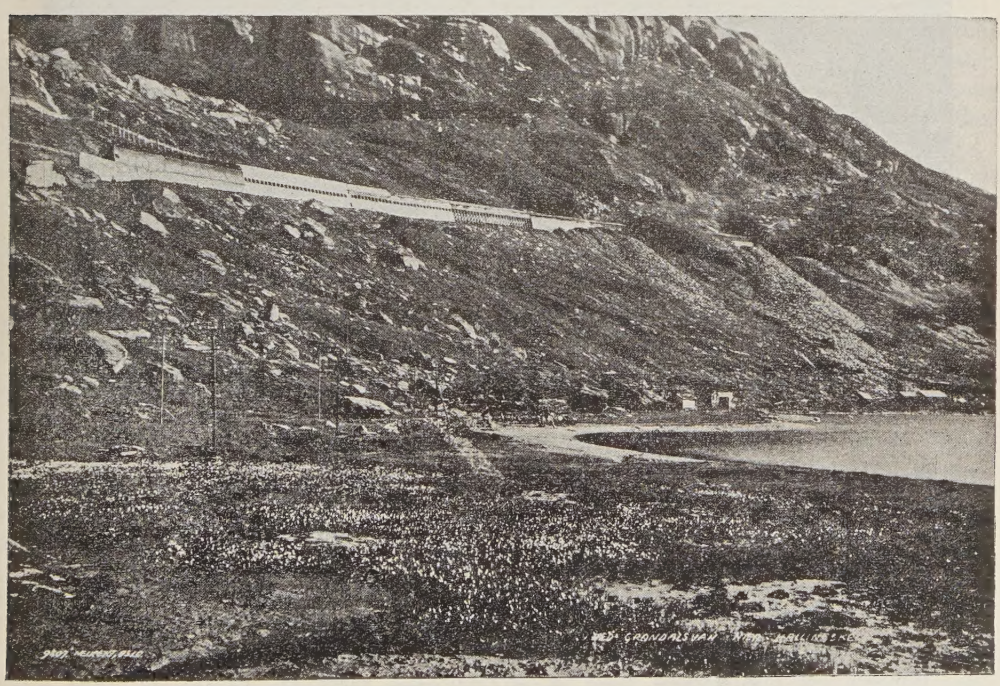


Fig. 309. — Snow sheds on the Bergen Railway.

Four great railways link or will link up Oslo with the coast :

a) the *Sörlandsbanen* (Southern line), building between Oslo and Stavanger;

b) the *Bergenbanen*, from Oslo to Bergen, with branches;

c) the *Dovrebanen*, from Oslo to Trondheim, with branches;

d) the *Nördlandsbanen* (Northern Railway), also under construction.

First, as to open lines :

a) The BERGENBANEN is one of the noteworthy railways in Europe. It was built in order to avoid the endless sea route from Bergen to Oslo, which formerly took 54 hours.

The distance from Bergen, 57 m. (187′) above sea level, to Voss is 65 km. (40.4 miles) as the crow flies, and

Fig. 310. — Entrance of the Gravahalsen tunnel, at Myrdal, Bergen Railway.

107 km. (66.5 miles) by railway. Here begins the ascent of the formidable 320 km. (200 miles) broad granite barrier formed by the Scandinavian Alps. The railway immediately wends its way between peaks 1 500 m. (4 900′) high (1) — further away they reach 2 000 m. (6 560′) above sea level — and just before reaching the station of Finse rises to a maximum of 1 301 m. (4 270′), Finse

(1) South the Hondalsnuten, 1 578 m. (5 177′), and north the Lönehorgje, 1 424 m. (4 672′).

being 190 km. (118.1 miles) from Bergen, and 1 222 m. (3 910′) above sea level, where there is often 4 m. (13′) of snow.

The other watershed is less steep. Gol (at the 289th km. = 180th mile), 207 m. (679′) above datum, marks the end of the more difficult section. Beyond, the line passes into the Hallingdal, where the profile is easier.

Like the Trondheim transalpine line, it rises to over 1 000 m. (3 280′) above sea level. The greatest heights on the two

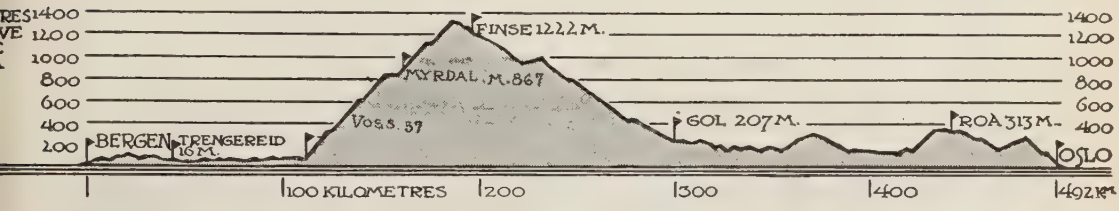


Fig. 311. — Gradient section of the Bergen Railway.

lines (figs. 311 and 312) are as follows :

Bergenbanen.

	Distance.		Altitude.	
	Km.	*Miles.*	*Metres.*	*Feet.*
Oslo	0	0	4	13
Nesbyen	186	115.6	169	554
Al	228	141.7	437	1 434
Ustaoset	264	164.0	991	3 251
Haugastol	275	170.9	988	3 241
Finse	302	187.7	1 222	4 009
Hallingskeid	323	200.7	1 110	3 641
Myrdal	336	208.8	867	2 844
Voss	385	239.2	57	187
Bergen	492	305.7	4	13

Dovrebanen.

Oslo	0	0	4	13
Hamar	126	78.3	?	?
Lillehamr	184	114.3	180	590
Otta	297	184.5	288	945
Dombas	343	213.1	659	2 162
Fokstua	362	224.9	952	3 123
Valasjo	373	231.8	943	3 093
Hjerkinn	382	237.4	1 017	3 337
Opdal	430	267.2	545	1 788
Stören	501	311.3	66	217
Trondheim	553	343.6	5	16

While on this subjet, it should be remembered that in Europe itself quite a number of railways, even important ones, have to climb to over 1 000 m. (3 280′) above sea level to get from one watershed to the other. The Swiss railways are classic examples, but many others in Austria, Spain and Italy reach similar altitudes. These railways are always difficult to build and costly to operate, and the services maintained are always interesting. Some additional information concerning this subject will be found in the chapter dealing with the Spanish railways.

A great many tunnels, including the longest in Norway, and half those longer than 1 000 m. (0.62 mile), had to be driven through the Scandinavian Alps :

Haverstingen	2 312 m. (1.43 mile)
Reinunga	1 615 m. (1.00 mile)
Gravahalsen	5 311 m. (3.30 miles)
Hyvingen	1 309 m. (0.81 mile)
Kräkeberget	1 057 m. (0.65 mile)

Altogether there are 184, 12 of which are on the western side, in the last 18 km. (11.2 miles) before reaching the summit. The Gravahalsen (fig. 310), the longest tunnel in the country (until those on the Southern Railway are completed) lies between Upsete (93rd mile, 2 790′ above datum), and Myrdal (97th mile, 2 845′ above sea level), before reaching the summit.

The *Bergen Railway* is one of the many Norwegian railways originally built to narrow gauge and afterwards converted to standard. It was in order to reduce the outlay that the first part of the line, from Bergen to Voss, was built to metre gauge. The construction of this railway was decided upon in 1875 and it was opened to traffic in 1883. Work was not resumed until 1894 and on a new location which involved driving the long Gravahalsen tunnel. The whole line was

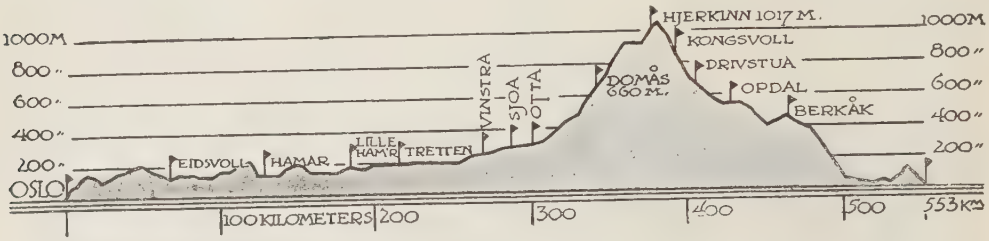


Fig. 312. — Gradient section of the Trondheim Railway.

opened to traffic on the 12th November 1897.

As we have seen, the two northern lines — the *Bergen* and the *Dovre* Railways — were built to serve the ports of Bergen and Trondheim. Branch lines providing quicker access to the coast, which are of particular interest on account of their steep gradients resulting from the mountainous nature of the district served, leave each of these railways before they reach their terminus. In the case of the *Bergenbanen* there are the *Flammsdal* and the *Voss-Granvin* (27 km. = 16.7 miles) branches, and the *Romsdalbanen* in that of the *Dovre* (Trondheim) line.

The FLAMMSDAL RAILWAY, some 20 km. (12 1/2 miles) long, descends directly from Myrdal [156th km. (97th miles) from Bergen and 866.8 m. (2 481′) above sea level] to Fretheim, on the Aurlandsfjord, which is an indentation of the Sognefjord (1). The average gradient is thus 4.34 % (1 in 23), with a maximum of 5.1 % (1 in 19.6), in spite of the truly remarkable way the development has been increased by the location adopted, which includes the Verma tunnel (figs. 313 and 314). On a length of 908 m. (3 000′), a difference in level of 46.30 m. (152′) is made good by the 1 in 19.6 gradient.

This artificial development also includes two helicoidal curves of 150 m. (492′) radius in opposite directions, joined by a short tangent. On this part of the layout, the line twice crosses its own track. Work on the tunnel was begun in June 1924 and the driving was completed on the 15th May 1935.

The other branch connecting the Bergen Railway with the coast links up Voss [107th km. (66th mile) from Bergen, 56.5 m. (186′) above sea level] with the Hardangerfjord at Granvin, by means of an electric railway 27 km. (16.8 miles) long, built by a private company, and which was opened last Summer.

(1) The Sognefjord, the longest of the Norwegian fjords, is 180 km. (111.6 miles) long from Sognefest to Skjolden, with an average width of 6 km. (3.7 miles) and a maximum depth of 127 m. (417′). The mountains on its shores reach up to 1 520 m. (4 985′).

The Trondheim Railway or *Dovrebanen* [Dovre is 331 km. (205.7 miles) from Oslo and 485 m. (1 590′) above sea level] crosses the Alps 1 017 m. (3 337′) above sea level at Hjerkinn [832nd km. (237th mile)], the climbing starting at Osta [297th km. (186th mile), 288 m. (955′) above sea level] and the descent ending in actual fact at Stören [501st km. (311th mile), 66 m. (217 1/2′) above sea level].

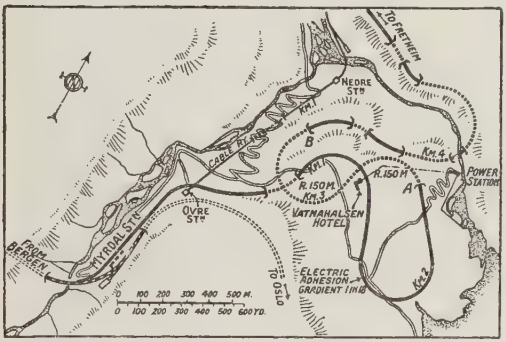


Fig. 313 (*). — The Vatnahal tunnel. Flammsdal Railway.

The climb takes place along the Gudoarandsai as far as Dombas, where the railway splits, a branch running straight to Romsdalfjord, while the main line, which crosses the Dovrefjell, goes on to Trondheim.

While the *Dovrebanen* runs round the western slope of the Rondane range, with mountains more than 2 000 m. (6 560′) above sea level, there is to the east of the range an alternative 3′ 6″ gauge route between Hamar and Stören, via the Osterdal and the Gauldal, which is only 9 km. (5.6 miles) longer than the former (238.6 miles via Elverun and Röros, instead of 233 via Dombas). On the other hand, the main line reaches an altitude of 1 017 m. (3 317′) above sea level at Hjerkinn, whereas the eastern line climbs no higher than 670 m. (2 198′) at Harborg.

Unlike Bergen, Trondheim is not a terminus. Besides the Storlien line which runs due east to the Baltic ports, the main line continues northward, along the Trondheimsfjord as far as Steinkjer [126th km. (78th mile)] and Grong [220th km. (137th mile)], the present terminus. A 50-km. (31 miles) branch line, opened in 1934, runs to the port of Namsos, the most northerly point to be reached by rail from Oslo. In fact, its latitude is 64° 30′.

The Romsdalbanen is a branch from the *Dovrebanen*, but such an important one that it can be said that the *Dovrebanen* splits up at Dombas, one branch leading to Trondheim, and the other to Aandalsnes, a port on the Romsdalfjord, which is reached after a run of 114 km. (70.8 miles) during which the line descends 655 m. (2 150′).

The location of the Romsdal line is difficult, and includes one of the most interesting double loops in the country (fig. 314). The depth of the gorges run through is illustrated by the fact that 10 km. (6.2 miles) from Aandalsnes, practically as it leaves the coast, this railway wends its way between the Romsdalshorn [1 550 m. (5 085′) above sea level] to the North, and the Frolltindane [1 760 m. (5 774′) above sea level] to the South.

XLVIII-3. — **Isolated lines.** — For the first time in this series of articles we come across railways running inland from the coast, which are still unconnected with the rest of the railway system.

Whilst it is of interest to see how such

(*) Reproduced from the *Railway Gazette*.

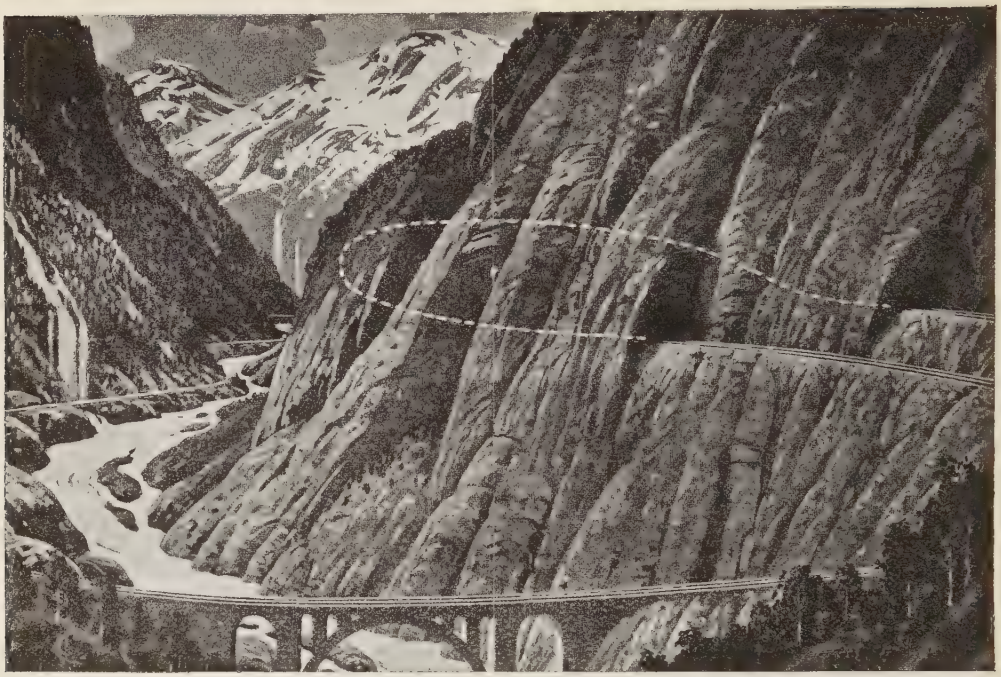


Fig. 314. — Artifical development of the Romsdal Railway at Verma.

railways serve the neighbouring districts, there is the additional interest that of necessity they will have to be linked up with the main system. Isolated lines are built to meet immediate local requirements; this is a stage to be found in all countries, like the subsequent railway policy grouping such lines into systems by the construction of appropriate connections and standardising the technical conditions on the same lines as those adopted for other parts of the country. This often involves changing the gauge.

Most of these lines (fig. 315) lie in the South, between the *Kragerö* and *Bergen* Railways.

TABLE 283.

ISOLATED RAILWAYS IN SOUTHERN NORWAY.

ORIGIN.			TERMINUS.				
Place.	Altitude.		Place.	Distance.		Altitude.	
	Metres.	Feet.		Km.	Miles.	Metres	Feet.
Arendal	8	26	Treungen . . .	91	56.5	249	826
Lillesand . . .	3	10	Flaksvatn (1) . .	25	15.5	18	59
Kristiansand . .	6	20	Byglandsfjord . .	78	48 5	207	679
Flekkefjord . . .	2	6 1/2	Stavanger . . .	150	93.2	5	16 1/2

(1) Via Tveille (7th mile), 71 m. (233′) above sea level.

Fig. 315. — The *Sörlandsbanen* and the isolated lines in the south west of Norway. The *Bergen Railway* and its branches.

The *Stavanger Railway* connects the ports of Flekkefjord and Stavanger, passing at the port of Egersund on its way. On its two inland sections it reaches altitudes of but 188 and 32 m. (617′ and 105′).

The construction of a line uniting these separate railways will completely alter their character.

The Sörlandsbanen (Southern Railway). — The construction of this railway is a very considerable undertaking (fig. 315).

The most westerly point reached by the railway from Oslo is the port of Kragero 101 km. (62.8 miles) from Nordagutu (starting point of the relatively new branch line serving it) (1), and 247 km. (153.5 miles) from Oslo. Beyond this point, however, are a number of harbours from which railways of varying lengths run inland : Arendal and Grimstad (2) (with the Treungen metre-gauge railway), Kristiansand (Byglandsfjord Railway), Mandal, and finally Flekkefjord, Egersund and Stavanger, which a railway joins already.

(1) The construction of the extension as far as Neslandsvatn with a branch line to Kragero, decided upon in 1908, was carried out between 1920 and 1927.

(2) Opened in 1908.

It is obviously tempting to link up these widely dispersed lines and give them direct communication with the capital. Apart from the political advantage of closer ties with outlying parts of the country, direct connection would enable Norway, like Denmark, to speed up the Anglo-Norwegian services. By means of the new railway and the Stavanger-Oslo railway, the date for the

Fig. 316. — The *Sörlandsbanen* at Hitterdalsvand.

completion of which is not yet fixed, it is hoped that Oslo will be reached in the evening of the second day's journey from London, instead of on the third day, as by the present route via Bergen.

The location of the new line, the construction of which was decided upon in 1923, crosses at right angles the mountains between the watersheds of the rivers running into the Skagerrak and involves many and lengthy tunnels. Among the chief ones are the following :

Grobei	1 986 m.	(1.24 miles)
Haegebostad	8 425 m.	(5.23 miles)
Kvineshei	9 065 m.	(5.63 miles)
Omland	1 590 m.	(0.99 mile)
Gyland	5 689 m.	(3.53 miles)
Voilås	1 448 m.	(0.90 mile)
Lölandsfjell	3 060 m.	(1.90 miles)
Trondas	3 153 m.	(1.96 miles)

From Neslandsvatn [221st km. (137th mile) from Oslo] the new line will con-

nect at Nelaug with the Arendal-Treungen railway [282nd km. (175th line)]. The 36-km. (22.4 miles) Nelaug-Arendal metre gauge section having been converted to 1.435 m. (4′ 8 1/2″), it was possible to inaugurate the through service from Oslo to Arendal (318 km. = 197.6 miles) on the 10th November 1935.

The next section, from Nelaug to Grovane [144th km. (89th mile) from the start] is to follow in 1938, and the trains will then reach the important town of Kristiansand by making use of the existing *State Railway* line for 20 km. (12.4 mile) between Kristiansand [164th km. (102th mile) from Oslo] and Byglandsfjord.

In passing, it should be noted that the short *Lillesand-Flaksvatn Railway* does not run far enough inland to reach the new *Southern Railway*.

The Danish authorities have seen in the construction of this railway the means of attracting traffic from Oslo to the Continent and even to England. For this purpose, starting in 1937, the Danish packet boats from Kristiansand, instead of plying to Frederikshavn, will serve the newly equipped port of Hirthals, which will considerably shorten the sea passage.

A private standard-gauge railway, 17 km. (10.5 miles) long, joins the port to Hjorring on the *State Railways*, whence the Jutland main line runs to the frontier station of Padborg. Thanks to the introduction of fast diesel trains between Hirthals, Padborg, and probably Hamburg, the time spent from Kristiansand will be halved : 10 hours instead of 20.

The traffic between Norway and Germany could with advantage be switched over from the Oslo-Trälleborg-Sassnitz route to the Oslo-Kristiansand-Padborg. The distance by rail in Norway would be approximately the same, 102 instead of 105 miles, and Denmark would profit by the through traffic to the detriment of Sweden.

The last section of the *Sörlandsbanen* will be the most difficult : it will connect Kristiansand [164th km. (102nd mile)] with Sirnes, a station on the 50 km. (31 miles) long metre-gauge *Flekkefjord-Stavanger* Railway; Stavanger is 136 km. (84.5 miles) from Sirnes. An additional section is projected between Egersund and Sandnes to avoid returning to the coast as does the metre-gauge line.

Isolated lines in the North. — Two *State Railways* lines and a couple of local lines are to be considered in this connection.

Table 284.

Origin.			Terminus.				
Place.	Altitude.		Place.	Distance.		Altitude.	
	Metres.	Feet.		Km.	Miles.	Metres.	Feet.
Thamshavn	...	...	Lökken	15	9.3	...	...
Skjönstu	13	43	Sandnes	23	14.3	14.7	9.1
Narvik	46	151	Vassijaure	46	28.6	(1)	(1)

(1) Bjornfjell, at the 37th km. (23rd mile), is 513 m. (1 683′) above sea level, and Riksgränsen, the first Swedish station, 521 m. (1 709′) above sea level.

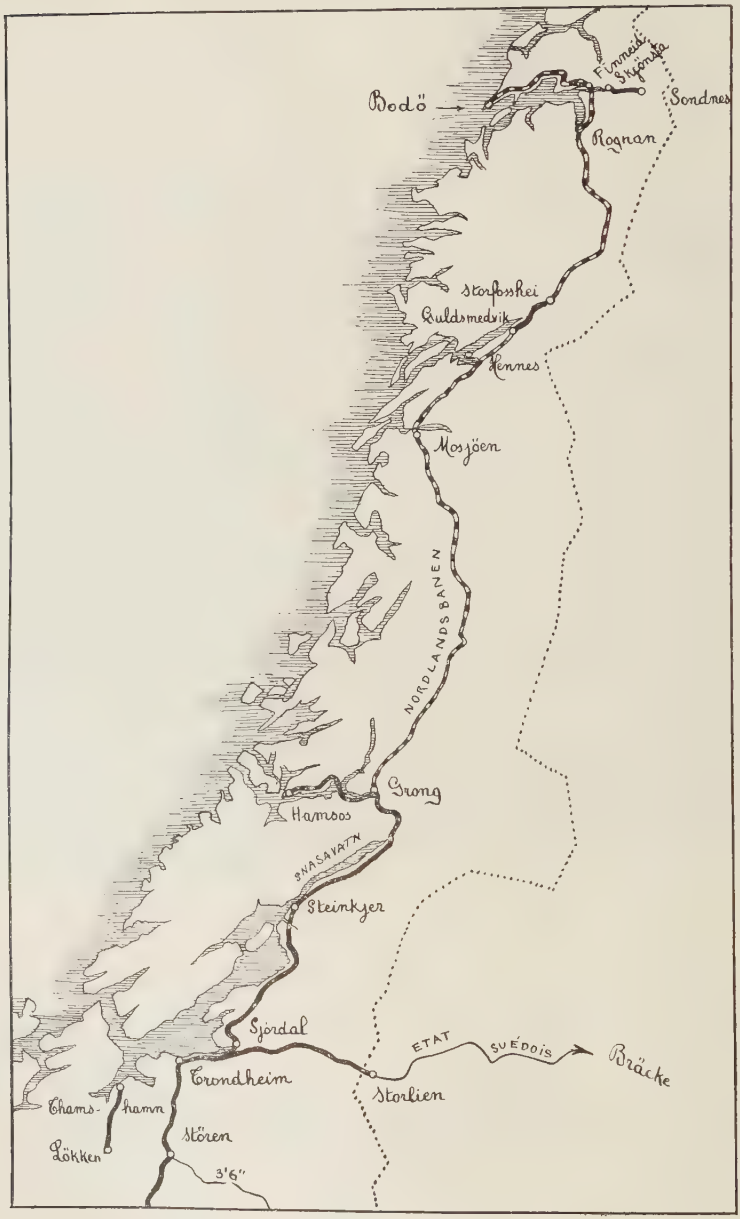


Fig. 317. — The *Nordlandsbanen.*

The Thamshavn railway is part of the Trondheim system with which it is linked up by the fjord. The Narvik railway is separated from the rest of the Norwegian system; it extends into Sweden as far as the Baltic port of Lulea by the Lapland Railway.

The Nordlandsbanen (*Northern Railway*) is to extend by some 186 km. (116 miles) the 773 km. (480 miles) of the Oslo-Grong line, and reach the port of Bödö, beyond the Arctic Circle. It is to run via Mosjöen, a port at the bottom of the Vefsenfjord, and Mo at the inner end of the Ranfjord (so that it can make use of the few miles of the small railway leading to Naeverness via the Dunderlandsdal). It will then run at some distance from the coast so as to avoid the Svartisen mountain range [1 591 m. (5 220′) above sea level], after which it will return to the sea and serve Saltdal, at the beginning of the Saltfjord which it will at first follow to the north. It is then to cross a secondary estuary which prolongs the fjord towards the Swedish frontier and thus reach Finneidet and Fauske, after which the railway will follow the northern shore of the fjord all the way to the port of Bödö, 67° 20′ latitude.

There is more or less direct communication from here to the frontier, as a navigable arm of the fjord leads from Finneidet to Skjönstu [some 30 km. (18.6 miles) long], from which place a railway line, the *Sulitelmaban*, 23 km. (14.3 miles) long runs to Sandnes.

Much further north than this, beyond the Arctic Circle, the *Narvik Railway* starting from Ofotfjord opposite the Lofoten Isles, will still remain isolated.

Completion of the Norlandsbanen, which will involve the driving of only two tunnels, the Medja (2 534 m. or 1.57 miles) and the Urstad (1 070 m. or 0.66 mile), may be expected for 1942.

XLVIII-4. — **Secondary centres.** — It will be readily appreciated that the Scandinavian Alps have proved an effective barrier to many railways, and that where any industry could settle, secondary centres have developed, such as Bergen and Trondheim, both of which are starting places for railways which remain on the western watershed of the Alps.

XLVIII-5. — **Electric traction.** — The oldest electric line in Norway is the Rjukan Railway, of the State system (fig. 318), equipped before the War for

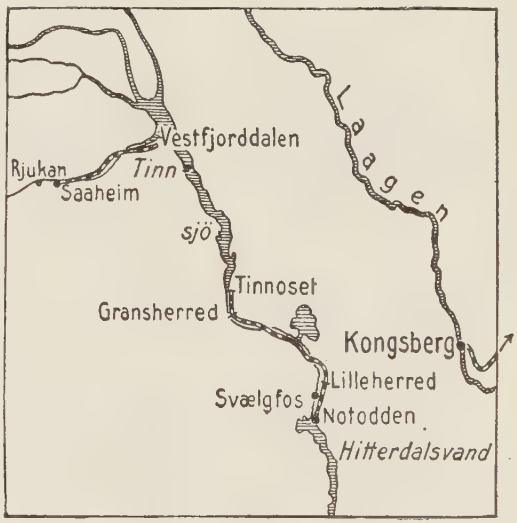


Fig. 318. — Electric line of the *Rjukan Railway*.

10 000-volt 15-cycle single-phase current. Like several other lines in the country, it provides a system of communication

by rail and water, the intermediate section on the Tinn being by a ferryboat service :

Hjuksebö-Notodden	9 km. (5.6 miles)	Formerly by boat on the fjord, now by rail.
Notodden-Tinnoset	31 km. (19.3 miles)	Railway.
Tinnoset-Moel	30 km. (18.6 miles)	Boat on the fjord (Tinnsjö).
Moel-Rjukan	16 km. (10.0 miles)	Railway.

Maximum gradients reach 1 in 37.

The NARVIK RAILWAY, in the extreme north, is one of the most interesting in the country, as it is a transverse international line between Norway and Sweden, without any connection with the rest of the Norwegian system. The quantity of ore to be carried is sufficient to make it a paying concern even without any more direct communication with the capitals.

Narvik, a Norwegian port always free from ice thanks to the warming effect of the Gulf Stream, is the western terminus of the *Lapland Railway* which crosses the peninsula transversely from Lulea, on the Baltic (fig. 339—*Sweden).*

TABLE 285.

ELECTRIFICATION OF THE NORWEGIAN STATE RAILWAYS.

(Sections in course of electrification are shown *in italics.*)

RAILWAY.	Length.	
	of line.	of track.
Oslo-Drammen-Kongsberg	99.5 km. (61.8 miles)	171 km. (106.3 miles)
Kongsberg-Hjuksebö	*37 km. (23.0 miles)*	*38 km. (23.6 miles)*
Notodden-Tinnoset	29.5 km. (18.3 miles)	36 km. (22.4 miles)
Notodden-Skien-Borgestad	*60 km. (37.3 miles)*	*73 km. (45.4 miles)*
Oslo-Lilleström	21 km. (13.0 miles)	85 km. (52.8 miles)
Oslo-Ski	*24 km. (14.9 miles)*	*56 km. (34.8 miles)*
Narvik-Swedish frontier	42 km. (26.1 miles)	55 km. (34.2 miles)
Voss-Eide	27 km. (16.8 miles)	28 km. (17.4 miles)

From Narvik, the line climbs steadily through difficult country by means of 1 in 63 gradients, curves of minimum radii prevailing over one third of the way (fig. 326). The maximum altitude is reached at the frontier. Electrified in the same way as the Swedish lines (16 000-volt single-phase 16 2/3-cycle current), the Narvik line is protected by numerous snow screens and sheds.

As the greater part of the railway lies beyond the Norwegian frontier we deal further with it in the Swedish section.

We have already mentioned the little VOSS-EIDE RAILWAY, the 27 km. (16.8 miles) of which were opened to traffic last Spring.

Finally the 15 km. (9.3 miles) long THAMSHAVN-LÖKKEN RAILWAY uses 6 000-volt 25-cycle current.

Apart from these isolated cases, the suburban lines round Oslo are being elec-

trified in stages as also sections of the international lines serving the capital.

The Ostfold Railway (169 km. = 105 miles) from Oslo to Moss and Kornsjö (frontier) was opened to traffic in 1879 and was completed by an alternative section 80 km. (50 miles) long between Ski and Sarpsborg. The traffic on this line justified its electrification which, like the other Norwegian lines, uses 15 000-volt single-phase 16 2/3-cycle current. When electrifying the Oslo East to Ski section the doubling of the track is also taken in hand. The following section is to be electrified in the near future.

The short electrified Oslo-Lillestrom section is in the same position as the Ski section, as the Trondheim and Magnor-Stockholm lines separate at Lillestrom.

Electrification is more advanced in the outer western suburbs and has already been completed in the case of the 146 km. (90.7 miles) from Oslo to Nordagutu via Kongsberg, a joint section. The electrification of the 90 km. (56 miles) of the Borgestad-Notodden-Tinnoset railway will complete this electric system, the biggest in the country.

XLVIII-6. — **Railcars.** — The introduction of diesels into Norway is of recent date; the first 4-wheeled railcars have been put into service in the Trondheim district in 1934. They haul one or two trailers (1).

XLVIII-7. — **Norwegian sleeping-car and restaurant-car services** (fig. 319 to 325). — Norway, Sweden and Finland

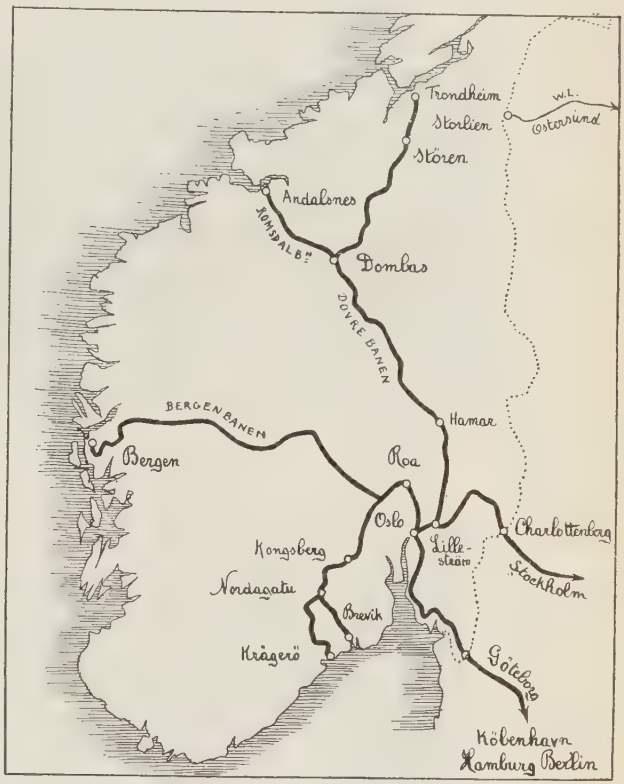


Fig. 319. — The Norwegian main lines and sleeping-car services.

are among the only European countries that operate their own sleeping- and res-

(1) Built by A./S. Strommens Verksted for a maximum speed of 88 km. (54.7 miles) an hour; their leading dimensions are :

Overall length	14.02 m.	(46′)
Outside width	3.10 m.	(10′ 2″)
Wheel base	8.50 m.	(27′ 10 43/64″)
Engines		270 H.P.
Weight empty	18.5 t.	(18.2 Engl. tons).
H.P. per ton		14.6
Do. with a 30-ton trailer.		5.25

Fig. 320. — Restaurant car, *Norwegian State Railways.*

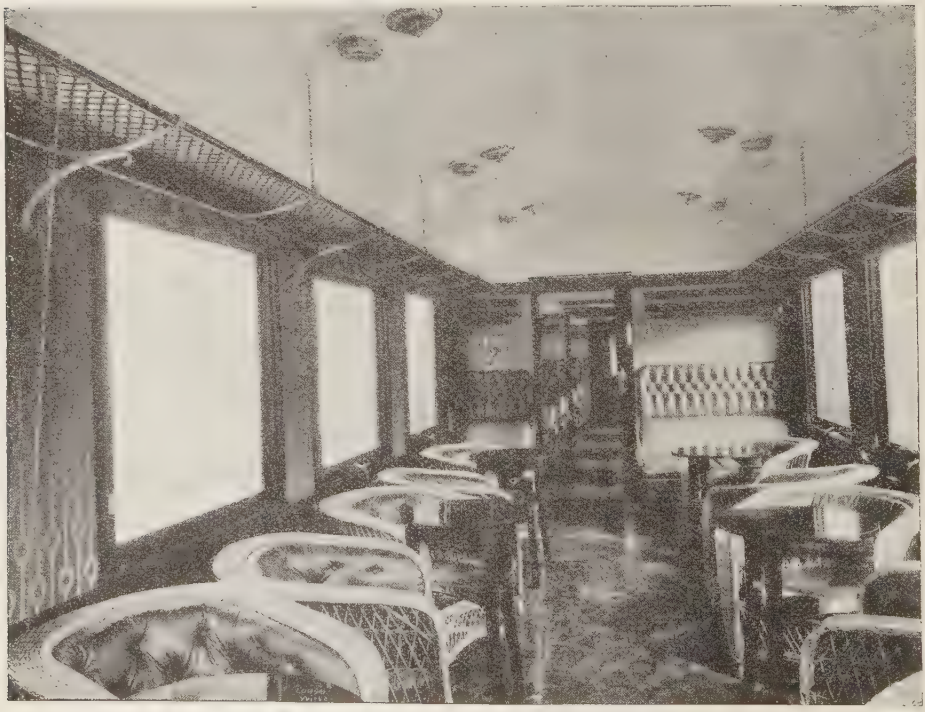


Fig. 321. — Saloon car, *Norwegian State Railways.*

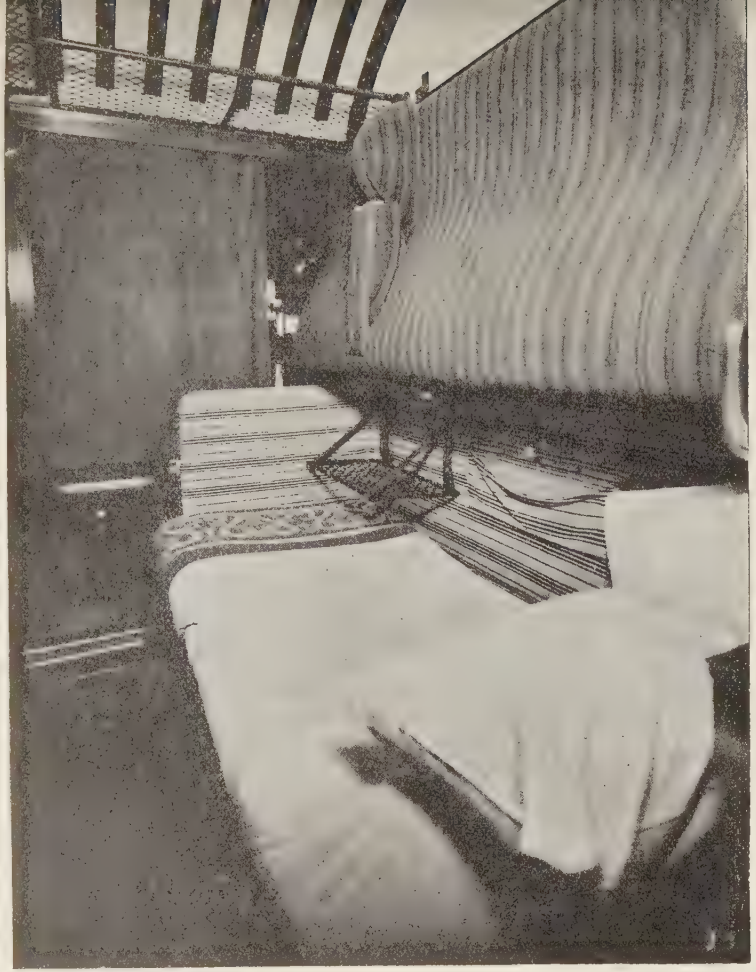


Fig. 322. — Second-class sleeping car compartment,
Norwegian State Railways.

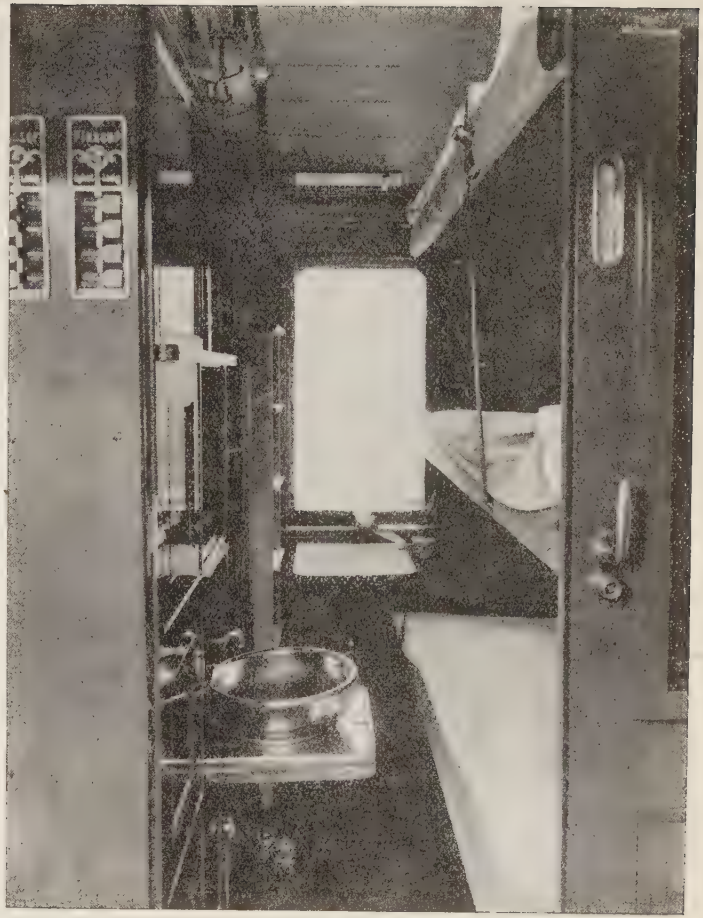


Fig. 323. — Interior of a 3rd-class sleeping car,
Norwegian State Railways.

taurant-car services without the assistance of the *International Sleeping-Car Company*. The vehicles are exceptionally comfortable, and the accommodation and attendance are excellent. The *Norwegian State Railways* were also the first to introduce 3rd-class sleepers, in 1907, over the 491 km. (305.1 miles) of the Oslo-Bergen Railway (fig. 319). These early vehicles had 12 compartments with 3 berths above each other. Unlike Swedish practice, where 3rd-class sleeping-car services were run for a certain time and then abolished, the Norwegian vehicles were fairly popular, and from the first year had an occupation coefficient of 52 %, which was very satisfactory. In spite of this, receipts were lower than those accruing from the 1st- and 2nd-class sleeping cars. During the second year's working there was a considerable increase in occupation in all three classes of sleeping car, and it was decided to introduce a 3rd-class sleeping-car service over the 550 km. (341.8 miles) from Oslo to Trondheim (fig. 323).

TABLE 286.

LEADING DIMENSIONS OF NORWEGIAN SLEEPING- AND RESTAURANT CARS.
(Figs. 320 to 325.)

TYPE OF CAR.	Sleeping car, 1st.-2nd.	Sleeping car, 1st.-3rd.	Sleeping car, 3rd.	Restaurant car.	Restaura
Date	1910	1929	1930	1926	193
Length over buffers	19.500 m. (64′)	20.100 m. (65′ 11″)	19.800 m. (64′ 11″)	20.100 m. (65′ 11″)	20.10 (65′ 1
Length of underframe	18.200 m. (59′ 8 9/16″)	18.800 m. (62′)	18.500 m. (60′ 8 3/8″)	18.800 m. (62′)	18.80 (62
Length of body	16.500 m. (54′ 1 5/8″)	16.900 m. (55′ 5 3/8″)	16.600 m. (54′ 5 9/16″)	16.900 m. (55′ 5 3/8″)	16.90 (55′ 5
Outside width	3.100 m. (10′ 2″)	3.100 m. (10′ 2″)	3.100 m. (10′ 2″)	3.100 m. (10′ 2″)	3.100 (10′
Bogie wheelbase	2.300 m. (7′ 6 9/16″)	2.300 m. (7′ 6 9/16″)	2.300 m. (7′ 6 9/16″)	2.300 m. (7′ 6 9/16″)	2.300 (7′ 6 9
Distance betw. bogie centres	13.800 m. (45′ 3 5/16″)	14.000 m. (45′ 11″)	13.700 m. (44′ 11 3/8″)	14.400 m. (47′ 3″)	14.00 (45′
Passengers carried { Day	30	15 + 24	48	40	40
Passengers carried { Night	20	10 + 18	36	...	...
Weight, empty	33.6 m. t. (33.2 Engl. t.)	34.4 m. t. (34.0 Engl. t.)	36.5 m. t. (36.1 Engl. t.)	33.2 m. t. (32.9 Engl. t.)	33.4 m (33.0 E
Weight per passenger carried	1 680 kgr. (3 700 lb.)	1 230 kgr. (2 710 lb.)	760 kgr. (1 675 lb.)	830 kgr. (1 830 lb.)	830 k (1 830

At the present time, the *Norwegian State Railways* maintain five inland sleeping-car services covering 1 559 km. (968.7 miles) (from Oslo to Trondheim, Aandalsnes, Bergen, Brevik, Kragero and Arendal), besides four international services which altogether cover 312 km. (193.9 miles) in Norway (from Oslo to Stockholm, Copenhagen, Berlin and Hamburg). There are also 4 restaurant-car

services, running from Oslo to Trondheim, Bergen, Halden (towards Kornsjö) and Malmö.

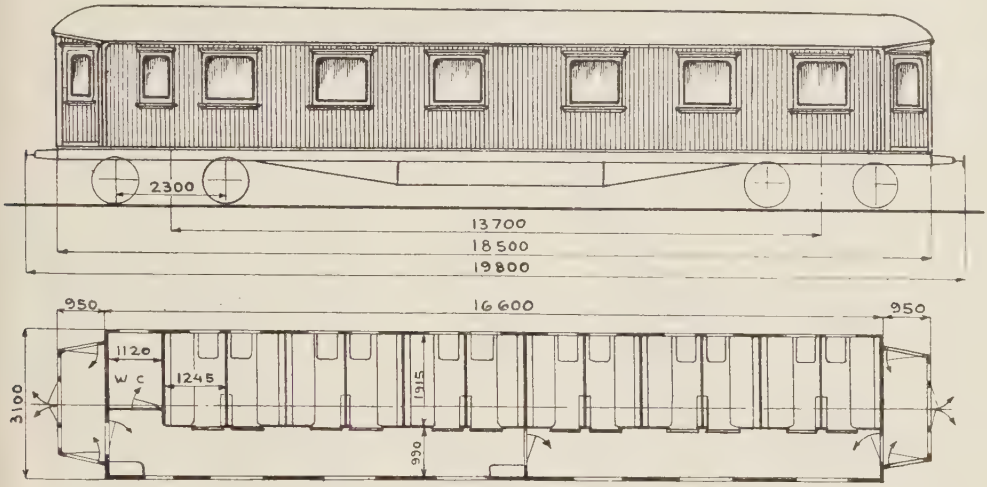


Fig. 324. — *Norwegian State Railway* sleeping car.

XLVIII-8. — **Train-speeds** (fig. 326). — There are no fast runs in Norway. The highest average speed in the 1935/36 Winter was 59 km. (36.7 miles) an hour — between Eidsvoll and Hamar, on the Trondheim line. The longest non-stop run is that from Hönefoss to Torpe (121 km. = 75.2 miles) on the *Bergenbanen;* and even on this run there is a conditional stop.

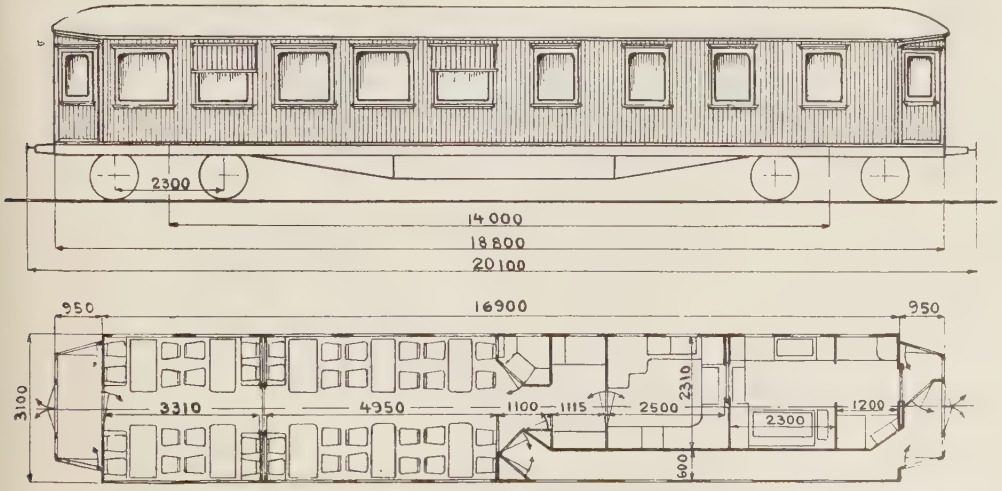


Fig. 325. — *Norwegian State Railway* restaurant car.

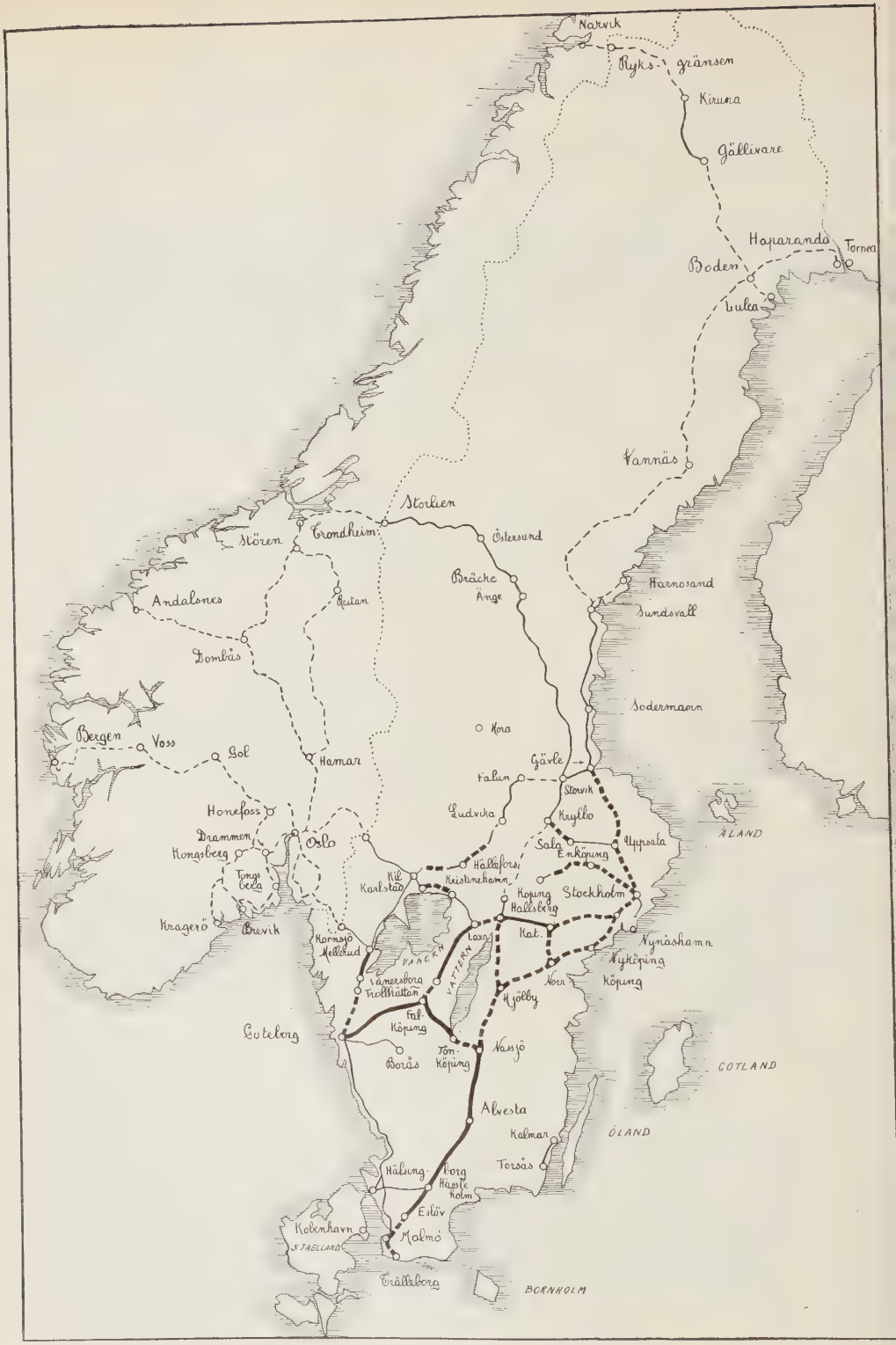


Fig. 326. — Cartogram of highest overall speeds on the *Norwegian* and *Swedish* State Railways (1935/36 Winter).

Table 287.

NOTEWORTHY NORWEGIAN TRAIN SPEEDS.

RUN.	Distance.		Time of departure.	Time spent.	Number of stops.	Speed.		Number of conditional stops.
	Km.	Miles.				Km./h.	M. p. h.	
Oslo-Moss-Kornsjö . . .	169	105.0	9.05 a. m.	3.12	4	52.8	32 8	...
Oslo O.-Moss	60	37.3	Do.	1.06	...	54.5	33.9	...
Oslo-Moss-Halden	137	85.1	Do.	2.27	3	53.2	33.1	...
Oslo-Charlottenberg (Stockholm)	126	78.3	9.10 a. m.	3.00	4	42.0	26.1	...
Oslo O.-Lilleström . . .	21	13.0	Do.	0.25	...	50.4	31.3	...
Oslo O.-Dombäs-Trondheim .	553	343.6	9.00 p. m.	10.25	21	53.1	33.0	5
Stören-Trondheim . . .	52	32.3	6.31 a. m.	0.54	...	57.7	35.9	...
Eidsvoll-Hamar	58	36 0	10.28 p. m.	0.59	...	59.0	36.7	...
Hamar-Lillehammer . .	58	36.0	11.34 p. m.	R 1.02	...	56.1	34.9	...
Trondheim (St.)-Hommelerk (Hell)	24	14.9	1.50 p. m.	0.26	...	55.4	34.4	...
Oslo O.-Bergen	492	305.7	*R 9.00* a. m.	*10.05*	*14*	*39.6*	*24.6*	14
Oslo O.-Hönefoss . . .	90	55.9	10.20 p. m.	1.43	...	52.4	32.6	1
Hönefoss-Torpe	121	75.2	R 2.49 a. m.	2.23	...	50.4	31.3	1
Oslo-V.-Brevik, via Drammen	202	125.5	...	...	...	...	...	...
Oslo-V.-Nordagutu-Arendal .	318	197.6	11.00 p. m.	6.20	16	50.2	31.2	...
Oslo-Sandvika	13	8.1	8.00 a. m.	0.14	...	55.5	34.5	...
Oslo-Drammen	53	32.9	11.00 p. m.	0 56	...	56.8	35.3	1
Stavanger-Flekkefjord . .	150	93.2	1.00 p. m.	3.21	7	44.8	27.8	...
Oslo V.-Eidanger	193	119.9	1.00 p. m.	4.17	8	46.9	29.1	Several.

(To be continued.)

[625. 143.2]

Heat-treating the ends of rails,

by J. SERVAIS,

Head of permanent way material testing section, Belgian National Railways Company.

The statistics of broken rails on the different railways reveal the fact that more than 80 % are broken at the fished ends.

This figure, moreover, does not include rails taken out of service for split ends or for cracks radiating from the bolt holes.

In many cases the inclusive percentage of rails with *broken and defective* ends exceeds 90 % of the total number of rails taken out of the track.

This damage is due to crushing of the rail head under the repeated blows from heavily loaded wheels running onto the rail ends. The running surface gets out of level and this sets up the characteristic hammering noise noticed when trains pass over the joints.

This hammering rapidly increases in intensity and loosens the whole joint besides damaging the bearing faces of the fish-plates. Once play is set up, the reacting forces increase and the ends of the rails become more highly stressed. Cracks develop in the web at the ends, either at the beginning of the head or the foot, or in the bolt holes.

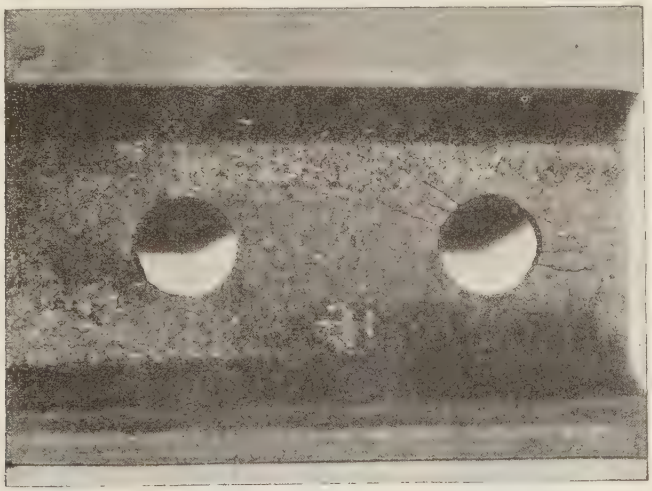


Fig. 1.

These cracks develop more or less quickly according to the degree of brittleness of the metal, run into one another, and finally end in the rail breaking in many cases.

Figures 1 to 3 show typical cases of this kind of defect.

During recent years large numbers of

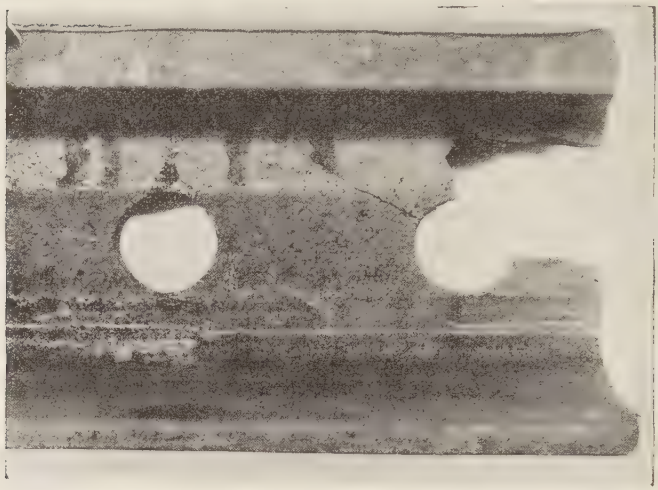


Fig. 2.

re-forged fish-plates have been used with the centre part reinforced, the idea being to take up the play due to the hammering down of the bearing surfaces.

This method of taking up play has often been found to be ineffective as the fish-plates cannot be made to match the very irregular bearing surfaces of the rail.

Building up the crushed ends *in situ* by welding has also been tried as a cure for the serious above-mentioned defects.

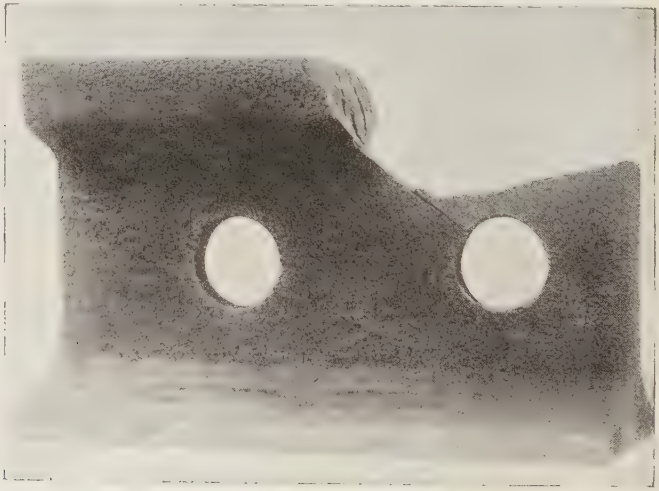


Fig. 3.

Obviously, this method can only be a palliative. The work depends on the skill of the workman and, in most cases, has to be done under awkward conditions, especially on lines carrying heavy traffic. The frequent failures recorded prove that this method is still little efficient and, in addition, is frequently costly.

Various methods of heat-treating the rails *in situ* have been suggested. The practical conditions are the same as for welding, and in both cases the reconditioned portion of the rail is very small and only affects the running surface.

What is wanted is to prevent failures occurring or at least to delay them sufficiently for the rail to last the normal period.

The rail, therefore, ought to be treated during manufacture when it can be properly controlled, and any rails on which the heat treatment has not been effective, rejected.

Rails heat-treated throughout may resist the damage as described above, but the plant involved is very considerable and costly.

A simpler and cheaper process which would give the greatest safety was, therefore, required.

In 1933, a number of rails were treated at the ends only, and put into service on the Belgian railways.

This treatment (1) consists in either quickly cooling the ends of the rails as they leave the rolls, or in reheating the ends of the cold rails (new or old) and cooling them off quickly to the desired hardening conditions. In both cases the specially designed equipment for cooling off the rails is simple.

By reheating the rail ends, an annealing effect is obtained which improves the structure of the metal and removes the internal stresses before hardening, an improvement not possible when the rails are cooled off directly from the rolls.

The different parts of the rail are hardened to a different degree, i.e. the hardening agents are applied under different pressures and for varying times to the different parts of the rail sections (running surfaces, side faces of the rail head, web near the bolt holes, and fishplate bearing surfaces) so that each part of the section shall be hardened in the most suitable way and its internal structure improved so as to ensure the rail ends having the mechanical properties best suited to withstand the stresses to which they are subjected in service. Compressed air is used as the cooling medium; it has been found to give the most regular and reliable results.

In September 1933, 58 rails weighing 50 kgr. per m. (100.8 lb. per yard), 27 m. (88 ft. 7 in.) long, heat treated at the ends, were laid at Tirlemont in the fast Liége-Brussels road; up to date the ends of these rails show very little wear, the maximum being 0.3 mm. (0.0118 in.), without fins.

The ordinary rails laid in 1933 at the same time, and even rails laid in 1934, show wear of 0.5 to 0.6 mm. (0.0197 to 0.0236 in.) with fins reducing the rail gap by 3 to 4 mm. (1/8 to 5/32 in.).

On the end-treated rails the wear only extends for a short distance (2 to 3 cm = 25/32 to 1 3/16 in.) as compared with 8 to 10 cm. (3 5/32 to 3 15/16 in.) on the ordinary rails.

The trains run definitely more smoothly over the end-treated rails.

(1) This patented process has been perfected in the Belval mills of the Société Métallurgique des Terres Rouges, at Esch-sur-Alzette (Luxemburg).

So far, not a single case of split web, or crack at the bolt holes has been recorded.

A further batch of sixty 27-m. (88 ft. 7 in.) end-treated rails were laid at Mont-St.-Guibert, on the Namur-Brussels line carrying very heavy traffic. These rails were found a great improvement on the ordinary ones.

In view of these results and the benefit derived from such treatment, the Belgian Railways laid, in 1935, some 3 000 end-treated rails, 27 m. long, in different sections of their main lines. A similar number will be laid during 1936.

* * *

Various mechanical tests have been carried out on, and micrographs taken from, such treated rails and they have confirmed the benefits that can be gained from this treatment when systematically applied.

The following are results of recent tests on end-treated rails, weighing 50 kgr. per m. (100.8 lb. per yard) taken from ordinary supplies, so that they can be considered as representing average values.

A. — *Chemical analyses.*

The analyses give results falling within the following limits :

SULPHUR	from 0.03 %	to 0.05	%.
PHOSPHORUS	from 0.04 %	to 0.065	%.
SILICON	from 0.12 %	to 0.18	%.
CARBON	from 0.40 %	to 0.48	%.
MANGANESE	from 0.88 %	to 1.05	%.

B. — *Tensile tests.*

The results obtained from rails as rolled and from treated ends on 13.8-mm. (17/32 in.) diameter test pieces cut from the rail head 17.5 mm. (11/16 in.) below the running face lie within the following values :

Mechanical properties.	*As rolled.*	*Heat-treated end.*
Yield point	35 to 40 kgr./mm². *22.2 to 25.4 Engl. tons/sq. inch.*	Average : 48 kgr./mm². *30.5 Engl. tons/sq. inch.*
Tensile strength	68.5 to 76 kgr./mm². *43.5 to 48.2 Engl. tons/sq. inch.*	Average : 81.9 kgr./mm². *52.0 Engl. tons/sq. inch.*
Elongation	21 to 15 %.	Average : 11.9 %.
Reduction in area	46 to 38 %.	Average : 20 %.

It should be noted that the test pieces are cut out 17.5 mm. (11/16 in.) below the running face, i.e. where the effect of the treatment is inevitably reduced.

As a matter of information, we cut two test bars 12 mm. (15/32 in.) below the running surface, one on each side of the longitudinal centre line of a hard rail, with a 0.46 % carbon content. The results obtained were as follows :

echanical properties.	*As rolled.*	*Heat-treated end :*	
		Test piece No. I.	Test piece No. II.
ld point	40.1 kgr./mm². *25.4 Engl. tons/sq. inch.*	59.5 kgr./mm². *37.8 Engl. tons/sq. inch.*	60.9 kgr./mm². *38.7 Engl. tons/sq. inch.*
sile strength . . .	77 kgr./mm². *48.9 Engl. tons/sq. inch.*	89.3 kgr./mm². *56.7 Engl. tons/sq. inch.*	91.8 kgr./mm². *58.2 Engl. tons/sq. inch.*
ngation	16 %.	9.5 %.	10 %.
luction in area . . .	37.8 %.	17.9 %.	20.5 %.

A test piece cut from the foot of the same rail gave :

Yield point . . . . . 53.5 kgr./mm² (34.0 Engl. tons/sq. inch).
Tensile strength . . . 86.6 kgr./mm² (55.0 Engl. tons/sq. inch).
Elongation . . . . . 12.5 %.
Reduction in area . . 23.1 %.

C. — *Drop tests.*

These tests were carried out on 1-m. (3 ft. 3 3/8 in.) lengths of rail on supports 800 mm. (2 ft. 7 1/2 in.) apart. The tup weighed 1 000 kgr. (2 204 lb.) and the height of drop was 6 m. (19 ft. 8 1/4 in.).

The first blow was given with the rail resting on the foot; the rail was then turned after each blow.

All the short lengths of rail with the treated end resting on one of the supports stood 4 successive blows without fracture and without cracks forming anywhere.

D. — *Resilience tests.*

The résilience of the heat-treated metal was as a rule not below that of the untreated metal, and varied between 2.72 to 6.33 kgrm./cm² (127 to 295 ft.-lb./sq. inch.) for hard steel of 76 to 78 kgr./mm² (48.2 to 49.5 Engl. tons/sq. inch) tensile.

E. — *Brinell hardness tests.*

The graph, figure 4, shows the increased hardness and its distribution longitudinally along the different faces treated.

The tests were made with a 10-mm. (3/8 in.) ball under a load of 3 000 kgr. (6 612 lb.), which was applied for 15 seconds.

F. — *Micrographical examination.*

The series of micrographs given below show the improvement in the structure obtained through the treatment. Cooling by compressed air tends to convert the pearlite into sorbite. The treatment affects the whole section of the rail. The transition between the heat-treated and the untreated parts of the rail is very gradual.

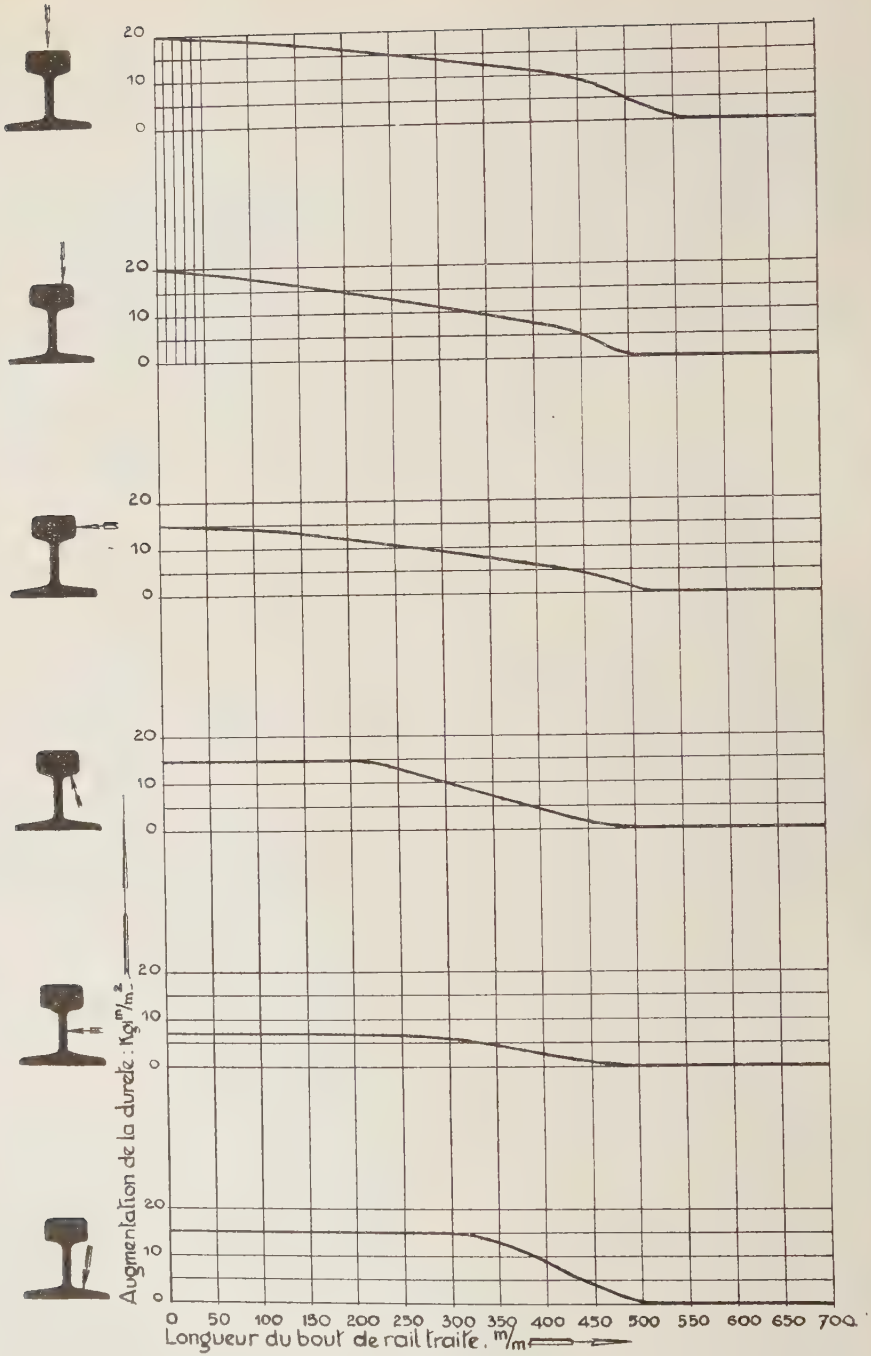
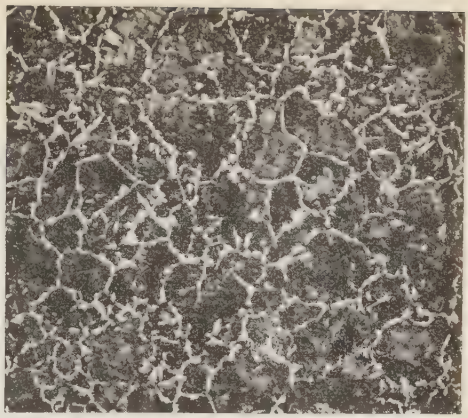

20
10
0
Augmentation de la dureté : Kg/m/m²
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700
Longueur du bout de rail traité . m/m

Fig. 4. — Graph showing the increase in hardness and its distribution in Belgian 50-kgr. (100.8 lb. per yard) rails with a minimum tensile strength of 70 kgr./mm² (44.4 Engl. tons per sq. inch).

Note : Augmentation de la dureté = increase in hardness. — Longueur du bout de rail traité = length of treated rail end.

75 diam.

Fig. 5. — 3 mm. (0.118 in.) below the running surface.

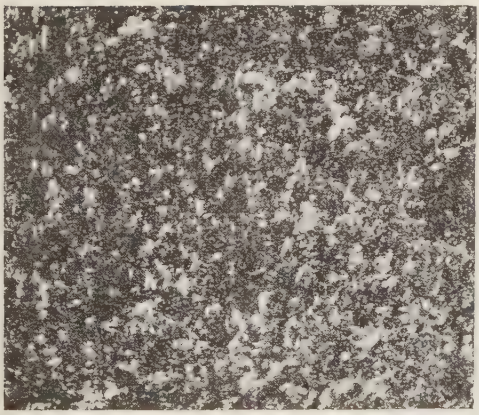


75 diam.

Fig. 6. — 15 mm. (0.591 in.) below the running surface.

Reticular structure. Procutectoid ferrite and pearlite.

Heat-treated end.



75 diam.

Fig. 7. — 1 mm. (0.039 in.) below the running surface.

75 diam.

Fig. 8. — 2 mm. (0.079 in.) below the running surface.

Sorbitic structure with isolated ferrite areas. The ferrite net is broken up.

75 diam.

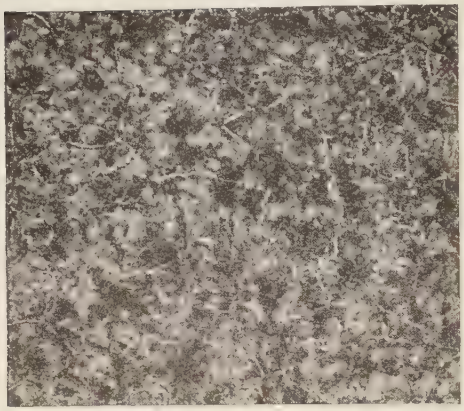
Fig. 9. — 3 mm. (0.118 in.) below the running surface.

75 diam.

Fig. 10. — 4 mm. (0.157 in.) below the running surface.

Sorbitic structure with isolated ferrite areas. The ferrite net is broken up.

The micrographs have been taken across the longitudinal section of the test bar.



75 diam.

Fig. 11. — 10 mm. (0.394 in.) below the running surface.

75 diam.

Fig. 12. — 15 mm. (0.591 in.) below the running surface.

Ferrite, pearlite and sorbite system.

75 diam.

Fig. 13. — Web. — Ferrite, pearlite and sorbite system. Fine crystallisation.

Conclusions.

The results the Belgian National Railways Company have obtained in service from rails with the ends heat treated are most encouraging.

The mechanical and metallographical tests show that wear and crushing of the rolling surface at the rail ends and wear at the fish-plate bearing surfaces is much reduced.

The treatment is easily controlled and improves the structure and mechanical properties of the metal in the different parts of the rail section, with a marked reduction in the number of cracks and fractures at the rail ends.

Naturally, as in all methods of hardening hard steel the cooling down must not be too quick, nor the original hardness too high. In this connection, the stable structure obtained by annealing the rail ends by reheating them from cold is specially recommended.

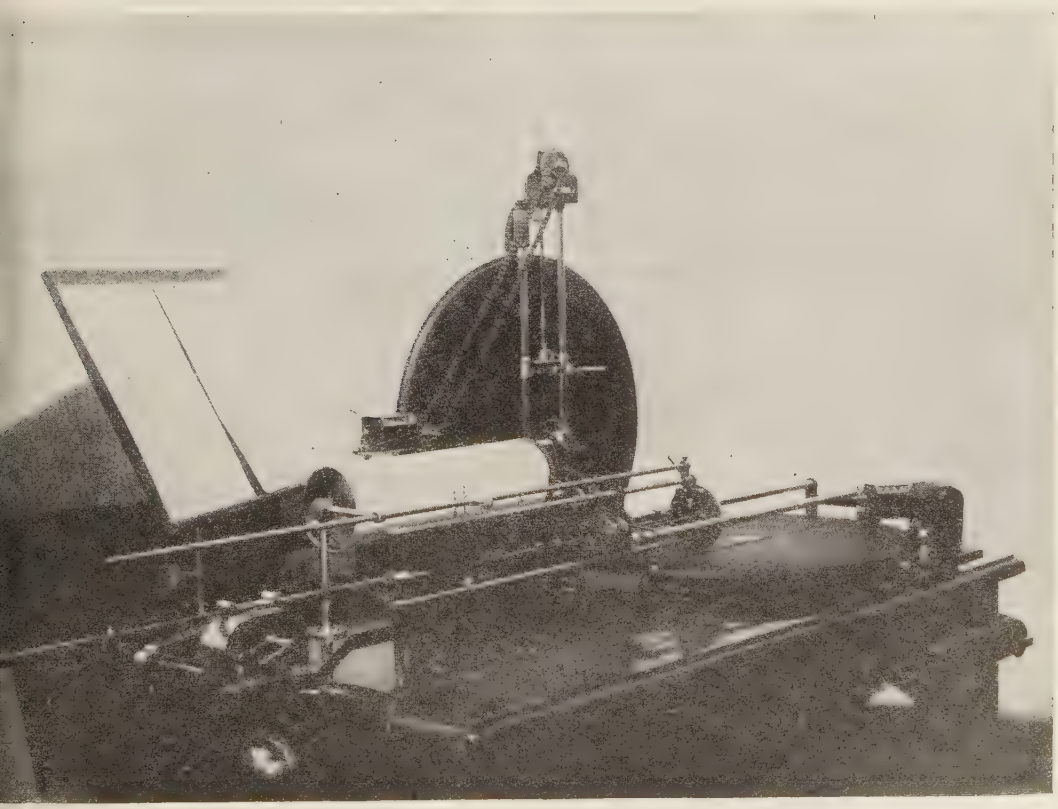
[656. 222]

Machine for calculating running times,

by F. CUYPERS,
Engineer, Locomotive Department, Belgian National Railways Company.

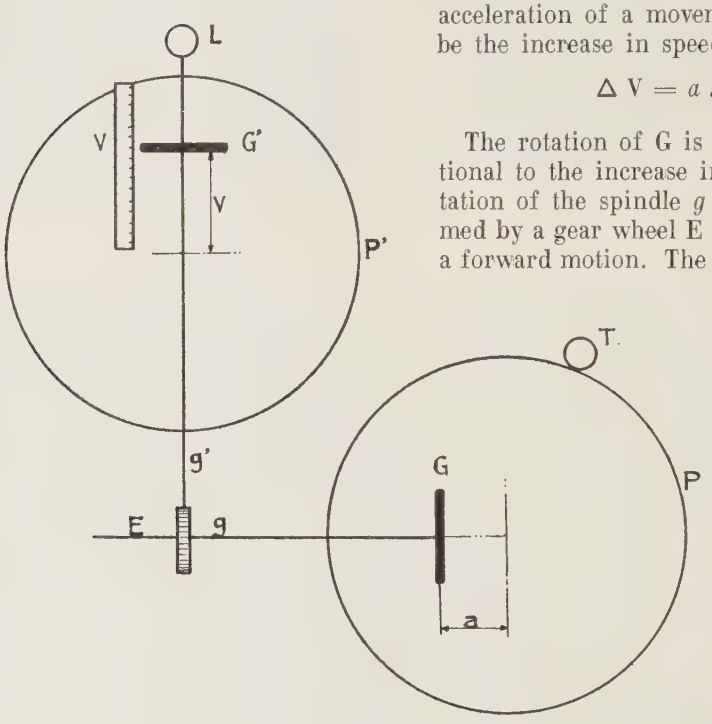
The Belgian National Railways Company, since 1933, has in hand the acceleration of all classes of passenger and goods trains.

The Locomotive Running Department in consequence was faced with the need of getting out a great number of new timings. The amount of work would have been very great if the times had been ascertained by the usual methods, elegant though they may be. It was therefore decided to build a machine which would enable the timings to be calculated quickly and easily. The machine was designed in 1933 and was in use in September of the same year.



Working principle.

A roller G is brought into contact with a revolving plate P. The number of revolutions of G is proportional to the product of the number of revolutions of P multiplied by the eccentricity *a* of the roller G on the plate P.



The rotation of P represents the time spent, for example, one revolution equals 1/10th of a minute. This convention ignores the speed of rotation of P.

The number of revolutions of the wheel G will therefore be proportional to $a \Delta T$, ΔT being the time increment.

If the eccentricity *a* represents the acceleration of a movement and if ΔV be the increase in speed

$$\Delta V = a \Delta T$$

The rotation of G is therefore proportional to the increase in speed. The rotation of the spindle *g* of G is transformed by a gear wheel E and a rack *g'* into a forward motion. The rack carries at its outer end a roller G' which is in contact with a plate P'. The forward movement of G' is therefore proportional to the increase in speed.

The instrument is set so that, at zero speed, G' is at the centre of P'. The eccentricity of G' relatively to P' will therefore be proportional to the speed, whereas the motion of plate P' is proportional to that of P. The rotation of G' will, in accordance with what has been said above, be proportional to the product

$$V \Delta T$$

which represents the increase ΔL in the distance covered

$$\Delta L = V \Delta T.$$

A counter T measures the rotation of

P; a graduated rule V shows the speed, and a counter L measures the rotation of G'.

The instrument therefore indicates, at any time, the speed reached and the distance travelled.

If, therefore, at each instant the acceleration a is known, the running speed and the distance travelled by a moving body can be calculated mechanically at each instant during the journey.

* * *

Application of the device to the calculation of the running times of railway trains.

The problem to be solved is the following :

Brussels (Quartier-Léopold) to Ottignies.

Stations.	Cumulative distances.	Speeds.	Gradients.
Brussels (Quartier-Léopold)	6 341		
	6 800	50	
Etterbeek	8 590		+ 8.4
	9 000	120	
Watermael	10 205		
	10 600	120	+ 0.6
Boitsfort	11 914		
Forêt de Soignes	13 585	120	+ 6.6
	14 750		
Groenendael	15 915		
Hoeylaert	17 600	120	
Malaise	18 800		— 4.7
La Hulpe	21 054		
Genval	22 800		
	23 250		
Rixensart	24 890		
	26 100	120	+ 11.0
Profondsart	27 169		
Le Buston	28 900	120	— 8.3
Ottignies	29 865		

To find at any moment the speed and the distance run by a train, the known factors being the characteristics of the line run over, of the locomotive, and of the load hauled.

a) *Line worked over.* — The distances, gradients, radii of curves, authorized speeds, location of the stations, junctions and signal boxes, etc., are known.

A table as above, giving the data re-

lating to the line used and taking the resistance of the curves into account, is prepared.

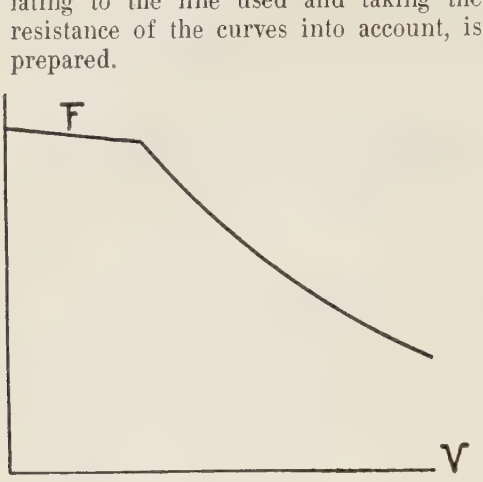


Fig. 1.

b) *Load hauled.* — The type of motive power and rolling stock used and its weight are known. The variation in the resistance r of this stock with the speed is also known (fig. 2).

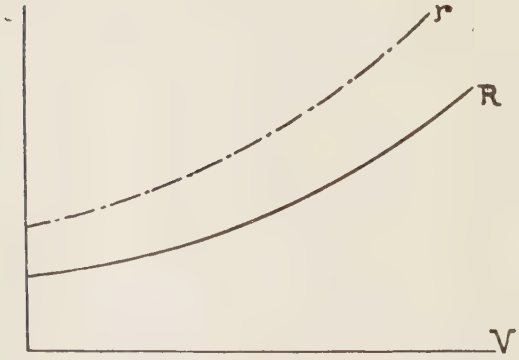


Fig. 2.

c) *Locomotive.* — The indicated tractive effort F of the locomotive at different speeds is known (fig. 1). The varying resistance R (fig. 2) of the locomotive at different speeds is also known. Subtracting the resistance R + r of the whole train from F, we get the law of variation of the accelerating power A with the speed when hauling the train considered *on the level* (fig. 3).

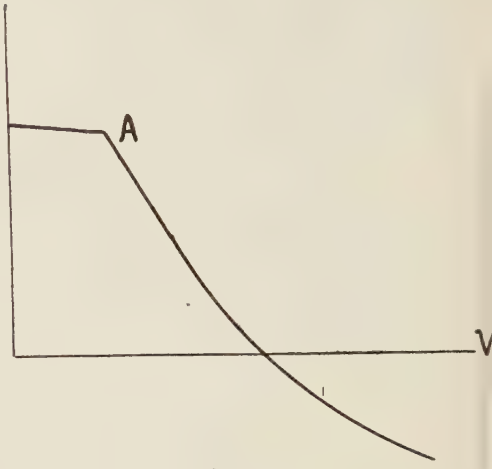


Fig. 3.

From this we deduce, based on general mechanics, the law of variation of the acceleration a with the speed of the train running *on the level* (fig. 4).

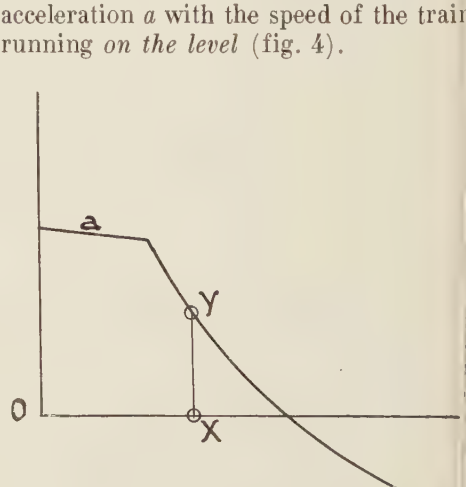


Fig. 4.

This diagram a V having been drawn all calculations in connection with t

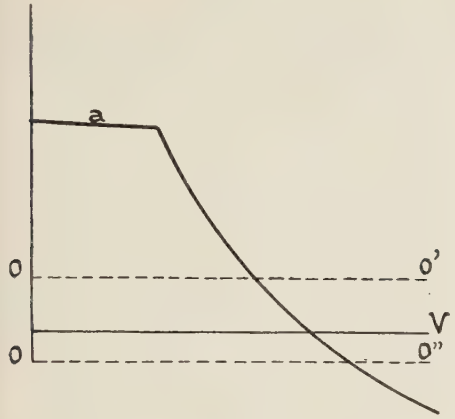


Fig. 5.

time-table can be made with the apparatus described, and without further investigations.

The machine is completed by a cylinder C (fig. 6). The diagram *a* V is wound upon the cylinder, the acceleration being calculated along the axis and the speeds on the circles normal thereto.

The cylinder C is rotated proportionally to G by the gearing E *e*.

G can make contact right across P from *d* to *d'*, the link *t* actuating crank *m*. The link *t* carries *a* pointer *i*.

When the speed of G' on the rule V is zero, the pointer *i* falls on the ordinate

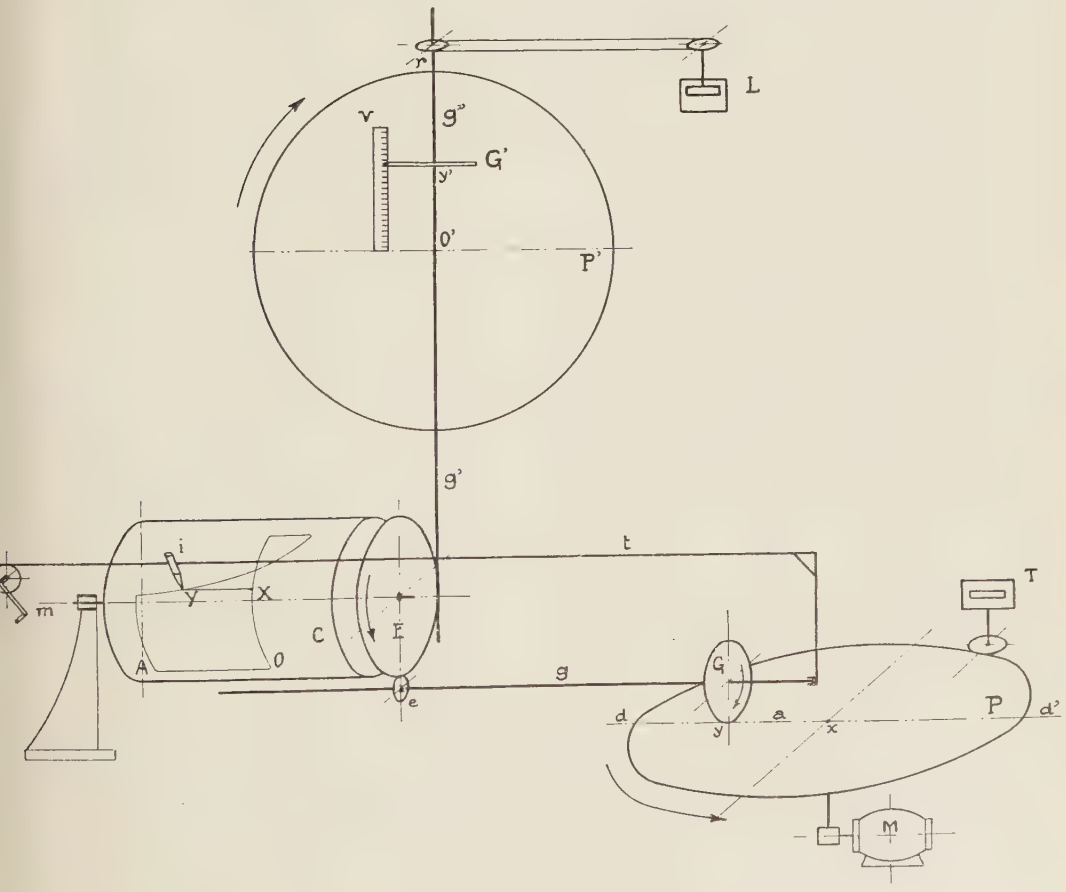


Fig. 6.

O A. The pointer *i* is so located that the distance $a = xy$ from the centre of P to G equals the acceleration XY drawn on the diagram *a* V.

If, therefore the machine is started up, P and P' will revolve, G will then be revolved in turn and measure the increase in speed. When G turns, the cylinder C also revolves and unwinds the diagram *a* V before the pointer *i*. By actuating crank *m*, the diagram can be followed with the pointer. Then at each instant and whatever the speed, $xy = a$ will always equal XY, i.e. the acceleration. Under these conditions, the rotation of G' will measure the distance travelled and the rule V will show the running speed. These figures are easily read on the counters T and L, and the rule V, so that the distance travelled and the running speed are known at each instant.

All the above refers to a train running on the level.

For a given gradient, it will be seen that the diagram V *a* (fig. 5) is still applicable if the line of the abscissæ is moved upwards to OO' by an amount equal to 0.981 cm. per sec. per sec. for each millimetre per metre of up gradient.

To effect this displacement on the diagram wound round the cylinder C the link *t* is graduated in up and down gradients (fig. 7), the zero of the scale cor-

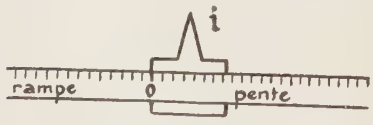


Fig. 7.

responding to the level. For a given slope, the pointer *i* is put opposite the proper figure.

* * *

The following points are to be noted :

If G lies to the left of the centre of P, the acceleration is positive and G' moves upwards onto P', indicating a rising speed.

If G lies to the right of the centre of P, the acceleration is negative, and G' moves downwards onto P', indicating a falling speed. This speed can be zero showing that the train is stalled; it can even become negative showing that the train is setting back.

If G falls in the centre of P, G will not revolve and G' will no longer move, indicating a constant speed, the acceleration being nil.

* * *

The machine is used to work up the timings, both of steam trains and of those operated by other forms of traction. All that has to be done is to make a diagram *a* V for these kinds of motive power.

* * *

Constructional features.

The plates P and P' are 500 mm. (19 11/16 inches) in diameter. They are covered with hard rubber so that the rollers G and G' will have sufficient adhesion. These rollers are made of bronze and are 92.6 mm. (3 41/64 inches) and 60 mm. (2 23/64 inches) in diameter respectively. The brass cylinder C is 102 mm. (4 inches) in diameter and the gears E*e* give a reduction of 160.

The machine is driven by a small electric motor M.

The following are the usual scales used : One revolution of P equals one tenth of a minute elapsed; the counter T shows hundredths of a minute; one turn of G equals an increase in speed of 1 km. per hour.

The diagram aV is so drawn that 2 mm. of abscissa represents one kilometre per hour, and 1 cm. of ordinate represents 1 cm. per sec. per sec. acceleration.

On the link t one millimetre per metre of rising gradient (1 in 1 000) is represented by 9.81 mm.

2 mm. on the rule V represent 1 kilometre an hour.

One revolution of G' represents a hectometre and the counter L reads to the nearest metre travelled.

These scales are connected by simple relationships which can be altered as necessary, for example to investigate the movements for which the starting acceleration reaches 80 cm. or 1 metre per sec. per sec.

The instrument is fitted with a bell which rings when the speed exceeds 120 km. (75 miles) an hour or when it becomes negative.

* * *

Thanks to this machine, instead of making the numeral and graphical calculations, always tedious and subject to error, all that is needed is to insert into the tables the values read off. Not only the journey time in terms of the load, but also the load for a given travelling speed can be calculated by means of this device.

[621. 132.8 (.43)]

Development of the turbine locomotive in Germany,

by Herr BURMEISTER, Chief Engineer, Essen.

(From Glasers Annalen.)

After a brief review of the design of the German turbine locomotives, the author gives the most important results of the tests of the Krupp-Zoelly turbine locomotive on the test plant and on the road. He describes the alterations made to reduce consumption. With the help of recent designs he shows the possibilities of future turbine locomotive development.

The first proposals to use the steam turbine for locomotive purposes date from the beginning of this century, when it was still in its initial stages of development. The steam turbine presents certain remarkable advantages over the reciprocating engine, which advantages it was felt should be applied to locomotives.

Fig. 1. — Turbine locomotive built by Messrs. Miami & Sylvestri in 1910.

The technical reviews published, in 1910, the first reports on the turbine locomotive built by Miami and Sylvestri, at Milan. This was a small shunting locomotive driven by four turbines in series. The turbines drove the two pairs of wheels of the locomotive through gears. The exhaust steam passed to the blower. This locomotive was used for trial runs on a test road and demonstrated, even at that early date, that the turbine could be used for railway traction purposes.

Quite a number of turbine locomotives have been built since that time; some have never got beyond the experimental stage, whereas others are in regular service.

Fig. 2. — Krupp-Zoelly turbine locomotive of the Reichsbahn.

The first experiments in Germany were made with the Krupp turbine locomotive (fig. 2) and in 1926 with that built by the Maffei Works (fig. 5). These two locomotives were built in accordance with Zoelly's designs after his first turbine locomotive built in Switzerland had made some satisfactory trial runs (1).

(1) Cf. WAGNER-WITTE : *Glasers Annalen*, Special Jubilee Number, 1st June 1927; LORENZ, Special Number of *Eisenbahnwesen*, Berlin 1925; IMFELD, *Z.d.V.I.* Vol. 70 (1926), p. 1 565.

The main features of the Zoelly type are : the turbine at the front end driving the coupled wheels through a train of gears by a jack shaft and rod drive; the water cooled surface condensers immediately behind the turbines for condensing the exhaust steam; the water cooling plant carried on the tender in which the heat is removed from the cooling water by direct contact, either by evaporation or by heating the atmospheric air.

Fig. 3. — Maffei-Zoelly turbine locomotive of the Reichsbahn.

The Reichsbahn possesses, in addition to the above two turbine locomotives, the turbo-power-tender built by Henschel & Sohn, Cassel (fig. 4) — also of the Zoelly type — now in service with a rebuilt P 8 engine. The power tender is driven by a turbine using exhaust steam from the reciprocating engine. The exhaust steam from the turbine is condensed in an evaporation surface condenser.

The three experimental turbine locomotives have undergone very extensive tests from which the benefits to be obtained from the turbine can be realised.

In 1924, the Krupp-Zoelly turbine was sent to the test plant, immediately it was finished. Power measurements (2) were made on the auxiliary equipment, and in particular on the auxiliary turbines to ascertain their behaviour under different loads and at different speeds. Finally very complete power tests were made on the main turbine and the steam consumption measured at the different loads and speeds usual in normal service. The power of the main turbine was transmitted, through a torsion indicator, by the secondary shaft of the main drive to brake dynamos, and measured at the same time. The arrangements adopted made it possible to determine the rotating force, even at low speeds, and thus investigate the starting conditions.

Subsequently to the tests on the experimental plant the turbine locomotive underwent many tests on different lines of the Deutsche Reichsbahn. First of all the locomotive worked trial trains intended to show the behaviour of the locomotive in ordinary service (fig. 5). These were followed by trials with the dynamometer car belonging to the Reichsbahn's Grunewald Test Office, and a brake locomotive, during which trials the power and consumption of the turbine were carefully measured (3).

The first trials with the engine already showed how very steadily it ran. This was to be expected as owing to the absence of unbalanced reciprocating parts, parasitic movements could only be set

Fig. 4. — Turbo-tender, with Henschel-Zoelly engine, of the Deutsche Reichsbahn.

(2) Cf. LORENZ, *Z.d.V.D.I.*, Vol. 70 (1926), p. 314.

(3) Cf. NORDMANN, *Z.d.V.D.I.*, vol. 7- (1930), p. 173.

up by the track. Then too, it was pleasant to find that nothing ever went wrong with the boiler, even under the heaviest load, no doubt due to using pure condensation water.

The opinion has been voiced in various quarters that the turbine locomotive has too low an initial torque, and

Fig. 5. — Krupp-Zoelly turbine locomotive hauling a trial train in 1927.

that the engine is difficult to start. The tests have completely disproved this opinion, as the engine has succeeded in starting easily even the heaviest trains and accelerating them quickly. Owing to its uniform turning moment the engine can start equally well from all positions and is less likely to slip than the piston locomotives.

By using the data obtained on trial runs and at the testing plant, the behaviour of the turbine locomotive under all working conditions can be calculated exactly. Figure 6 gives the power curves at the boiler limit corresponding to a total evaporation of 9 300 kgr. (20 500 lb.) per hour. The draw-bar horse-power measured during trial runs is shown by curve 1, whilst curve 3 gives the power at the turbine gear wheel as measured at the test plant. The distance between 1 and 3 represents the losses between the turbine shaft and the draw-bar. The accuracy of these losses was proved by the road tests with shut regulator. These tests again revealed the good riding of the locomotive, due to the excellent lubrication of the moving parts, unlike the more rough and ready lubrication of the reciprocating parts of the ordinary locomotive : pistons, crossheads and valve gear. The distance between curves 2 and 3 corresponds to the loss of power resulting from the reverse turbine working at the same time. This loss, especially at high speeds, is very considerable.

The trials on the testing plant gave the steam consumption of the auxiliary turbines in terms of the condition of the steam in front of the turbine, so that in running tests the steam consumption could be calculated from the recorded steam condition.

The data recorded during the trial runs and the calculations give a very clear idea of the proportion of steam used by the auxiliary turbines under different loads.

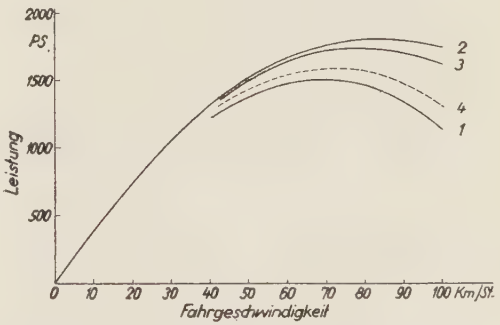


Fig. 6. — 4-6-2 T 18 1001 (Krupp-Zoelly) turbine locomotive. Power developed at maximum boiler output (steam consumption 9 300 kgr. = 20 500 lb. per hour).

1. Draw-bar horse-power
2. Horse-power at the main turbine shaft (forward)
3. Power at the gear wheel on the turbine shaft

} before reconstruction.

4. Designed draw-bar horse-power after rebuilding.

Note. — Leistung = power. — Fahrgeschwindigkeit = speed. — Km./St. = kilom. per hour.

The top curve of figure 7 shows the proportion by weight of the steam used by the auxiliary turbines; at full power it is about 18 1/2 %, and it increases rapidly as the power falls. This curve, however, does not give a true picture of

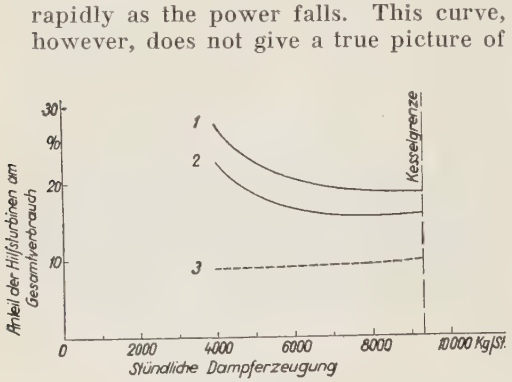


Fig. 7. — 4-6-2 T 18 1001 (Krupp-Zoelly) turbine locomotive. Steam consumption of the auxiliary turbines at 80 km. (49.7 miles) an hour.

1. Proportion of the total steam used by the auxiliary turbines.
2. Proportion of the steam used by the auxiliary turbines from the total power available in the total steam production, with adiabatic expansion } before rebuilding.
3. Estimated proportion the steam used by the auxiliaries bears to the total power the total steam produced could develop, with adiabatic expansion. } after rebuilding.

Explanation of German terms:

Anteil der Hilfsturbinen am Gesamtverbrauch = proportion taken by the auxiliary turbines in the total consumption. — Stundliche Dampferzeugung = steam produced per hour. — Kesselgrenze = boiler limit.

this consumption, as part of the steam goes to the exhaust steam feedwater heater and is used therefore, with only a small temperature drop whereas the steam from the main turbine is expanded to condensing pressure. The consumption of the auxiliary turbines should, therefore, be expressed in heat units which can be converted into mechanical work in the ideal engine. This gives curve 2 of figure 7, representing the ratio of the total steam consumption of the auxiliary turbines multiplied by the adiabatic drop in temperature in each, to the corresponding value of the total quantity of steam supplied by the boiler. As may be seen, this curve of the true consumption of the auxiliary turbines also rises quickly as the quantity of steam produced decreases, and reaches relatively high values when little steam is produced.

The auxiliary turbines were fed with live steam from a special superheater; part of their exhaust steam was passed to the feed-water heater, and the remainder to the condenser (fig. 8). This

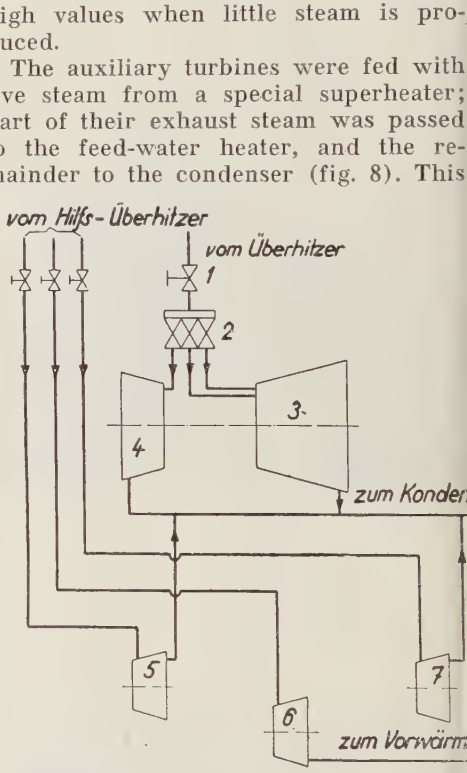


Fig. 8. — Diagram of the steam distribution in the 4-6-2 T 18 1001 turbine locomotive before reconstruction.

1. Locomotive regulator.
2. Valves.
3. Forward (main) turbine.
4. Backward turbine.
5. Induced draught turbine driving the draught fan.
6. Cooling turbine (driving the cooling fan).
7. Turbine driving the pumps (feed pump, brake compressor, and cooling water circulating pump).

Explanation of German terms:

Vom Hilfs-Überhitzer = from the auxiliary superheater. — Zum Kondensator = to the condenser. — Zum Vorwärmer = to the feed water heater. — Absperrventil = stop valve.

made their regulation quite independent, so that they could be run at the best speed, as determined under test, by a suitable steam valve opening. This method had the drawback that owing to the constant changes in the power developed by the locomotive, the driver had to watch the working of the auxiliaries the whole time and continually adjust their speed to suit the power of the locomotive. This remark applies especially to the draught turbine, the speed of which has to be proportional to the steam given by the boiler, as the heat given off on the grate is mainly governed by the quantity of air drawn in. Whereas in piston locomotives, this draught is automatically regulated by the blast, if the turbine locomotive is not properly fired, there may be a great loss of heat, as excess air or other defects upset efficient combustion.

Then, too, very great savings of steam can be effected by reducing the speed of the auxiliaries when coasting.

The fuel consumption during the constant speed and power trials with the dynamometer car and brake locomotive was 35 to 40 % of that with the 3-cylinder superheated class R10 2-8-2 locomotive, and 25 % of that with the standard superheated class 01 4-6-2 locomotive (4). The high-speed trials with the brake locomotive between Berlin and Hanover, showed appreciably lower savings, only about half those under constant power and speed conditions. When closely investigated, this is ascribed to :

1. The continual variation in power made it very difficult for the enginemen to regulate the working of the turbines to suit, and in particular to completely stop the induced draught turbine and slow down the cooling turbine to the speed required to maintain the vacuum in the condenser.

2. When starting, the main turbine used more steam than at high speeds.

3. Shunting in stations at very low speeds and power also affected the coal consumption unfavourably, especially when running in back gear as, owing to the ventilation losses in forward running, the back gear turbine was made with very few stages so that its maximum efficiency was only obtained at speeds much higher than the maximum in fore gear.

Consequently the turbine locomotive was redesigned and rebuilt. First of all, by using a back gear turbine which could be cut out when running forward, the steam consumption should be reduced appreciably both when running forward by cutting out the braking action and when shunting as then, owing to the high gear ratio, the turbine is working under efficient conditions at quite low speeds. The design was still further improved by fitting the back gear turbine with a clutch and reverse gear so that this turbine could be used for low-speed forward running as well, or in other words making it into a shunting turbine. In addition, with this arrangement when starting a train, the shunting turbine can be used alone or in conjunction with the main turbine so as to make a more economical start. Figure 9 shows the design of the shunting turbine.

Another improvement was to arrange the three auxiliary turbines in series, namely the cooling turbine driving the cooling fan and the cooling water circulating pump, which turbine was to be transferred to the tender when rebuilding the engines; the auxiliary turbine driving the draught fan; and the turbine driving the condensing and feed pumps, the brake compressor, and the rotary pump for the make-up water and for the condenser injector (fig. 10). In the former design, the draught turbine and the turbine driving the pumps work-

(4) Cf. Nordmann, *Z.d.V.I.*, vol. 74 (1930). p. 173.

ed on the full drop in pressure between the boiler and the condenser, and the cooling turbine on the still considerable temperature drop between the boiler and the feed water heater; with this arrangement the efficiencies of the

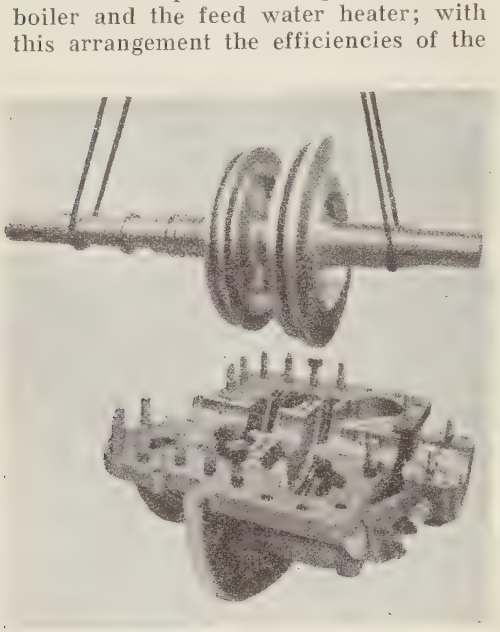


Fig. 9. — Shunting turbine fitted to the Krupp-Zoelly turbine locomotive.

turbines were poor, the quantity of steam used being small, and the temperature drops considerable. By arranging them in series the temperature drop is divided and the quantity of steam increased, the efficiencies of the auxiliary turbines being raised 30 to 50 %. A further saving is obtained by feeding the auxiliary turbines with steam bled after the first stage of the forward running turbine. In addition, by using this layout the regulation is perfectly automatic, and almost free from losses in the auxiliary turbines, the steam for which is no longer wire-drawn under part load but has done work in the first stage of the forward running main turbine. As this steam is not available when coasting, the pressure-reducing valve (11, fig. 10) has been provided, and the auxiliary turbines draw their live steam through it from the boiler. This altered steam distribution has reduced the steam consumption of the auxiliary turbines by about one half. The lower curve of figure 7 shows how, after rebuilding, the steam consumption of the auxiliaries varies with the steam produced.

At the same time as the layout was rearranged, the blast and smoke box

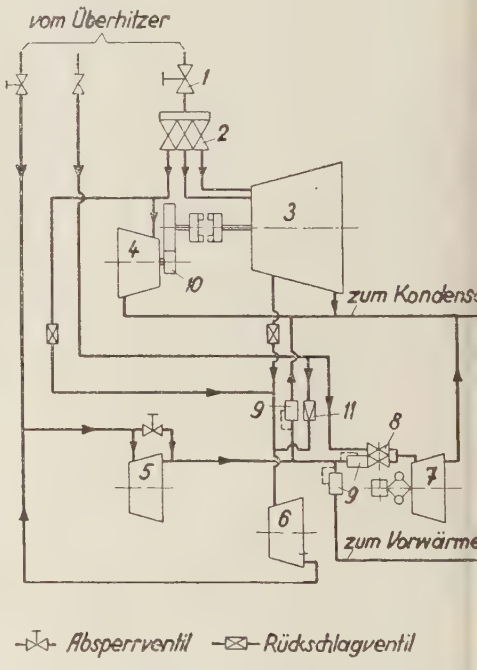


Fig. 10. — Diagram of the steam distribution in the 4-6-2 T 18 1001 locomotive after rebuilding.

1. Locomotive regulator.
2. Valves.
3. Forward turbine.
4. Starting turbine.
5. Induced draught turbine driving the draught fan
6. Cooling turbine (driving the cooling fan).
7. Turbine driving the pumps (feed pump, brake compressor, and cooling water circulating pump).
8. Revolution counter of the pump turbine.
9. Overflow valves.
10. Reverse gear.
11. Pressure-reducing valve.

Note: Rückschlagventil = Non-return valve.

were also simplified. The draught turbine with reduction gearing and radial fan was replaced by the simple equipment of figure 11 in which a shaft running in ball bearings carries the radial fan and the driving turbine with its small Curtis wheel.

Figure 6 shows the expected increase in power, which will mean an appreciable fuel economy under constant working conditions. The coal consumption will be further reduced by the more efficient start with the starting turbine and especially by the reduction in steam consumption in station shunting and when coasting. Then too, the auxiliary turbines can no longer be mishandled. The trial runs to be made in the near future with this rebuilt Krupp turbine locomotive will show the extent of the improvements effected.

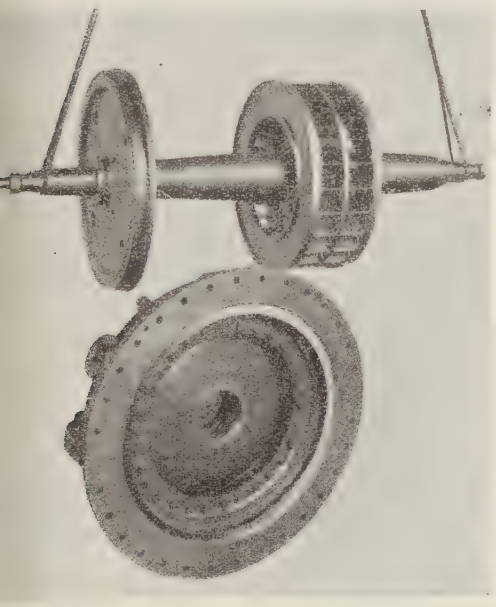


Fig. 11. — Induced draught equipment as fitted to the Krupp-Zoelly turbine locomotive.

The Maffei turbine locomotive has in its turn been thoroughly tested, both at the test plant and on the road, and its good riding qualities, like those of the Krupp locomotive, showed themselves at once. Its economic value was affected adversely, however, by the action of the back gear turbine and the relatively high consumption of the auxiliary equipment.

Consequently, a scheme for rebuilding this locomotive, incorporating much the same modifications as in the case of the Krupp engine, was prepared and put in hand. Special mention must be made however, of the fact that, by doing away with the reverse running turbine, it has been possible to fit a new improved main turbine of increased power. The Maffei turbine locomotive is now in service in the Munich division and will shortly undergo elaborate tests, and measurements.

When undergoing tests before being taken over by the Reichsbahn, the Krupp locomotive gave the very good coal figure of 0.75 kgr. (1.65 lb.) per draw-bar horse-power at 80 km. (49.7 miles) an hour. This is equivalent to 0.625 kgr. (1.372 lb.) per H.P.-hour at the turbine shaft. After rebuilding the figures were 0.70 and 0.60 kgr. (1.54 and 1.32 lb.), i.e. much below the figures of the reciprocating locomotives. When considering these values, it must be remembered that the turbine locomotive was built twelve years ago and that excepting the draught equipment, replaced when rebuilding, the original turbines and auxiliaries are in use. This machinery is now out of date. By replacing the main turbine, by improving the cooling tender, and by raising the initial steam temperature from 300 to 450° C. (572 to 842° F), a temperature presenting no difficulty with the steam turbine, it will be possible to reduce the coal consumption by a further 10 to 15%.

From the tests with the existing turbine locomotives, much information has been collected, which will be used for future developments, and by means of which it is now possible to build what

will probably be the standard type turbine locomotive, to which no essential alteration will have to be made.

Figure 12 illustrates a condensing turbine locomotive with an ordinary Stephenson type boiler; the pressure is 23 kgr. (327 lb. per sq. in.) which is not excessive for this type. In view of the efficiency of the boiler and to avoid the turbine exhaust being overheated, the steam temperature has been limited to 450° C. (842° F.) even though a higher

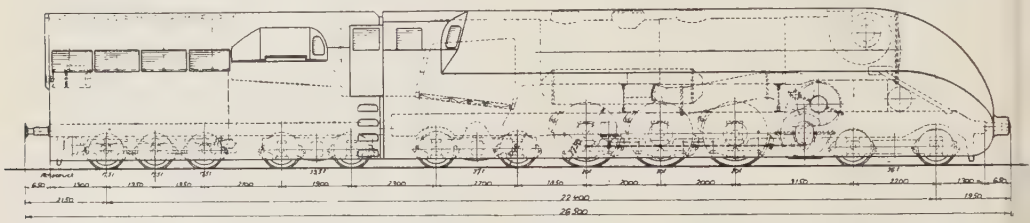


Fig. 12. — 4-6-4 turbine locomotive.

Locomotive:

Gauge	1.435 m. (*4 ft. 8 1/2 in.*).
Weight in working order	133 t. (*130.9 Engl. tons*).
Adhesive weight	60 t. (*59.0 Engl. tons*).
Maximum power of the turbine at full boiler ouput	3 0000 H.P.
Boiler heating surface	190 m² (*2 045 sq. ft.*).
Superheated steam temperature	450° C. (*842° F.*).
Boiler pressure	23 kgr./cm² (*327 lb. p. sq. in.*).
Condension pressure	0.15 kgr./cm² (*2.1 lb. p. sq. in.*).
Maximum speed	175 km. (*108.7 miles*) *p. h.*

Tender:

Weight in working order	86 t. (*84.6 Engl. tons*).
Water	30 t. (*29.5 Engl. tons*).
Coal	9 t. (*8.85 Engl. tons*).

temperature would still further improve the thermal efficiency without interfering with the turbine. The ordinary type of boiler has been retained on account of its great pratical advantages and because, so far, no high-pressure locomotive boiler has satisfactorily passed its service tests.

The pressure of 23 kgr. (327 lb.) was adopted without hesitation as the boiler of the Maffei turbine locomotive built for almost the same pressure has given excellent results, possibly largely because it is fed with pure condensation water. The locomotive is driven by a main turbine and one for shunting and starting, in accordance with the arrangement adopted when rebuilding the two German engines. In this case, the auxiliaries are also regulated automatically by the way their driving turbine is fitted. The room required by the water cooling equipment, also located on the tender, has been much reduced by the improved design. The tender as a result can carry 30 tons of water and 9 tons of fuel. The water is sufficient for a run of 400 km. (250 miles) when the engine develops 2 000 draw-bar horse-power at a speed of 170 km. (105.6 miles) an hour. Sufficient coal is carried for about twice this distance. Figure 13 gives particulars of the power and consumption.

Under constant working conditions this locomotive may be expected to show a 10 % coal saving over a corresponding modern reciprocating engine. The same saving should be obtained in service as the alterations have almost completely overcome the waste of steam at starting and when shunting. A further saving is to be expected in maintenance costs in comparison with reciprocating engines, as well designed and built turbines, gears

and auxiliaries should require less attention. Boiler maintenance should, moreover, be reduced to the minimum as the boiler is fed with condensed water which should preserve the boiler. The customary weekly or fortnightly washing

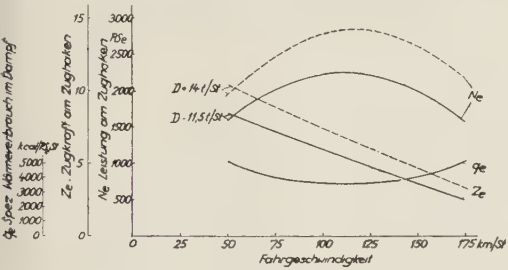


Fig. 13. — 4-6-4 turbine locomotive (fig. 12) for a speed of 175 km. (108.7 miles) an hour.

Ne and *Ze* = Power and draw-bar pull at maximum output (hourly steam consumption D = 14 tons) and at boiler limit (D = 11.5 tons per hour). — *qe* = specific consumption of heat in the steam at full boiler output starting from the temperature of the feed heater.

Explanation of Germans terms:

Spez. Wärmeverbrauch im Dampf = Specific consumption of heat in the steam. — Zugkraft am Zughaken = Drawbar pull. — Leistung am Zughaken = Draw-bar horse-power. — Fahrgeschwindigkeit = Running speed.

out is not needed, and besides the saving in wages this represents, the engine availability is increased. The greater steadiness in running resulting from the absence of reciprocating parts reduces the wear and tear and this also means a saving.

With a boiler heating surface of 190 m² (2 045 sq. ft.), the locomotive develops 3 000 shaft horse-power continuously, for which power a reciprocating engine would have required 300 m² (3 230 sq. ft.) of heating surface, which represents the limit of manual firing. A turbine locomotive with 300 m² (3 230 sq. ft.) heating surface would develop about 4 700 H.P. and could still be hand-fired.

A further fuel saving of up to 45-50 % can be made by raising the pressure up to about 40 kgr./m² (560 lb. per sq. in.) but this means a special type of high-pressure boiler. Figure 14 is the diagram of a proposed locomotive of this type, for a maximum speed of about 140 km. (87 miles) an hour.

The boiler is of the La Mont type, with forced circulation, for a pressure of 40 kgr. (560 lb.) and a superheated steam temperature of 325° C. (617° F.). As condensed water is used, no difficulty is to be feared on the water side. The layout of the engine is new, the cab being at the leading end with the high-pressure boiler immediately behind it.

The turbine, auxiliaries and surface condenser are all arranged at the tralling end. This layout has been made possible by the use of pulverised coal, which can be carried on the tender further away from the firebox and the cab.

The layout is so compact that a continuous shaft horse-power of 3 400 can be developed without exceeding the limiting wheel base of 22.40 m. (73 ft. 6 in.) due to the length of the turntables.

This locomotive will consume about 3 200 calories (12 700 B.T.U.) per H.P.-hour at the turbine shaft, and so comes into the consumption figures of stationary engines.

The steam turbine is of special interest for extra-high speed locomotives.

The locomotive, figure 15, is a design intended to show the possibilities of the turbine locomotive. This 4-6-4 locomotive with separate tender and 2 m. (6 ft. 6 3/4 in.) diameter driving wheels can attain a speed of 200 km. (124 miles) an hour.

The difficulties experienced when starting with locomotives intended for such high speeds, and which are due to the fact that the engine being specially designed for the high speeds and consequently with insufficient starting power, do not apply to turbine locomotives with a starting and shunting turbine. Figure 16 gives the working particulars of this locomotive.

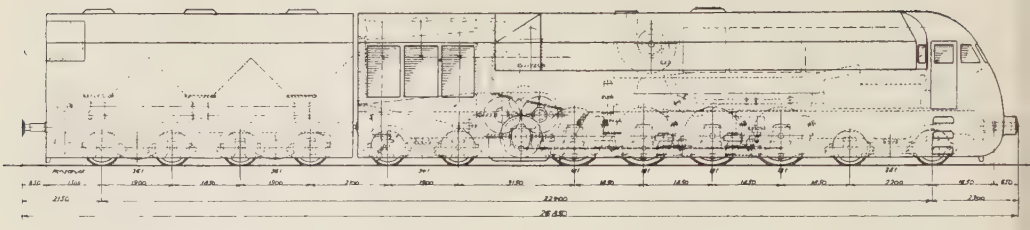


Fig. 14. — 4-8-4 turbine locomotive with La Mont boiler.

Locomotive:

Gauge	1.435 m. (*4 ft. 8 1/2 in.*).
Weight in working order	134 t. (*131.9 Engl. tons*).
Adhesive weight	72 t. (*70.9 Engl. tons*).
Maximum power developed by the turbine at full boiler ouput	3 400 H.P.
Boiler heating service	105 m² (*1 130 sq. f.*).
Temperature of superheated steam	525° C. (*977° F.*).
Boiler pressure	40 kgr./cm² (*569 lb. p. sq. in.*).
Condenser pressure	0,15 kgr./cm² (*2.1 lb. p. sq. in.*).
Maximum speed	140 km. (*87 miles*) p. h.

Tender:

Weight in working order	72 t. (*70.9 Engl. tons*).
Water	24 t. (*23.6 Engl. tons*).
Coal	10 t. (*9.8 Engl. tons*).

The cab is again placed at the leading end, which gives the driver a good look-out and enables the engine to be fully streamlined. The engine is cased in and is carried a the trailing end, like the preceding one. By using pulverised fuel the coal can be carried at the extreme back end and the fireman's work is

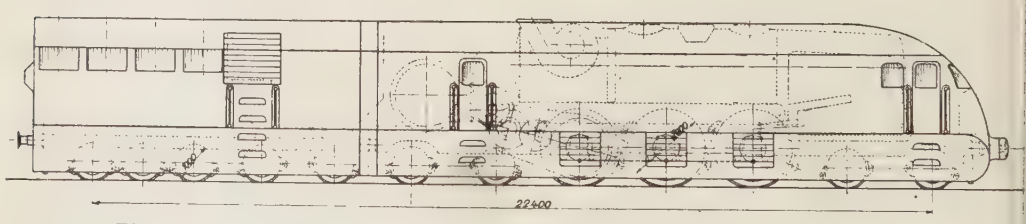


Fig. 15. — 4-6-4 turbine locomotive for a speed of 200 km. (124 miles) an hour.

Locomotive:

Gauge	1.435 m. (*4 ft. 8 1/2 in.*).
Weight in working order	134 t. (*131.9 Engl. tons*).
Adhesive weight	60 t. (*59.0 Engl. t.*).
Maximum power developed by the turbine at full boiler ouput	3 000 H.P.
Boiler heating service	190 m² (*2 045 sq. ft.*).
Temperature of superheated steam	450° C. (*842° F.*).
Boiler pressure	22 kgr./cm² (*313 lb. p. sq. in.*).
Condenser pressure	0.15 kgr./cm² (*2.1 lb. p. sq. in.*).
Maximum speed	200 km. (*124 m. p. h.*).

Tender:

Weight in working order	86 t. (*84.6 Engl. tons*).
Water	30 t. (*29.5 Engl. tons*).
Coal	9 t. (*8.9 Engl. tons*).

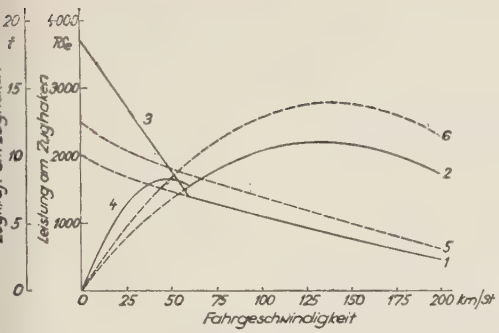


Fig. 16. — 4-6-4 turbine locomotive (fig. 15) for a speed of 200 km. (124 miles) an hour.

1. Draw-bar pull when the main turbine is working to full boiler capacity (steam consumption 11.5 tons per hour).
2. Draw-bar horse-power when the main turbine is working to full boiler capacity.
3. Draw-bar pull when running with the starting turbine (steam consumption 10 tons per hour).
4. Draw-bar horse-power with the starting turbine.
5. Draw-bar pull when running with the main turbine at maximum power (steam consumption 14 tons per hour).
6. Draw-bar horse-power when running with the main turbine at maximum power.

lightened as much as possible to allow him to keep a good look out, a great advantage with such high speeds.

In countries in which the fuel cost is low, and the capital charge on the locomotive high, the use of direct exhaust turbines can be considered.

Figure 17 is a 4-8-4 turbine locomotive with a normal type boiler, with a pressure of 23 kgr. (327 lb. per sq. inch) and a steam temperature of 450° C. (842° F.). It only differs from the usual reciprocating type of locomotive by having a steam turbine in place of the usual cylinders and valve motion. The exhaust steam from the driving turbine passes direct to the blower. A small turbine, which can be cut out when not needed, is provided for starting and shunting purposes. A locomotive of this kind has still many advantages over the reciprocating type. The larger fuel saving due

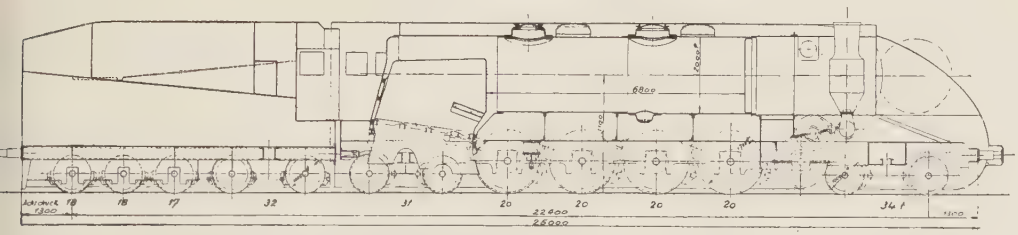


Fig. 17. — 4-8-4 non-condensing turbo-locomotive.

Locomotive:

Gauge	1.435 m. (*4 ft. 8 1/2 in.*).
Weight in working order	145 t. (*142.7 Engl. tons*).
Adhesive weight	80 t. (*78.7 Engl. tons*).
Maximum power developed by the turbine at full boiler ouput	2 800 H.P.
Boiler heating service	270 m² (*2 906 sq. ft.*).
Temperature of superheated steam	450° C. (*842° F.*).
Boiler pressure	22 kgr./cm² (*312 lb. p. sq. in.*).
Maximum speed	140 km. (*87 miles*) *p. h.*

Tender:

Weight in working order	85 t. (*83.7 Engl. tons*).
Water	37 t. (*36.4 Engl. tons*).
Coal	9 t. (*8.9 Engl. tons*).

to condensing and to the better boiler conditions when condensed water is used, has to be foregone, but the good riding properties and the low engine repair costs are retained, and in addition there is some 10 % fuel economy.

[656. 211. 5]

Watertight passenger subways,

by J. CERIEZ,

Engineer, Belgian National Railways Company.

The Belgian National Railways have built many passenger subways in large stations during the last few years, to obviate passengers crossing the lines.

These subways are all built in reinforced concrete in the form of a hollow box with walls of from 0.20 to 0.40 m. (7 7/8 in. to 1 ft. 3 3/4 in.) thickness according to the width of the subway and whether it is under the lines or platforms.

Experience has shown that leakage is apt to occur, even in dry ground, owing to water getting through the thin walls, either as the result of natural causes such as storms, or of accidents such as a broken main.

The absorption capacity of the ground is rarely great enough to prevent hydrostatic pressure being set up momentarily outside the walls.

Furthermore, the subway being more than 3 m. (9 ft. 10 in.) below the surface, in itself forms a natural basin into which the water in the adjacent ground collects.

The following, therefore, appear to be the minimum precautions to be taken almost in every case to ensure the subways being watertight :

1. The subway should be given a layer of watertight material all over the side walls where in contact with the soil, to make good any possible defects in the workmanship, resulting from the difficulty of building subways in sections under the lines remaining in service.

2. The land along both sides and ends of the subways should be properly drained, for instance by means of earthenware pipes covered with porous material up to the track level.

The water should be drained off into a nearby ditch or culvert, either by gravity, if possible, or by a pump.

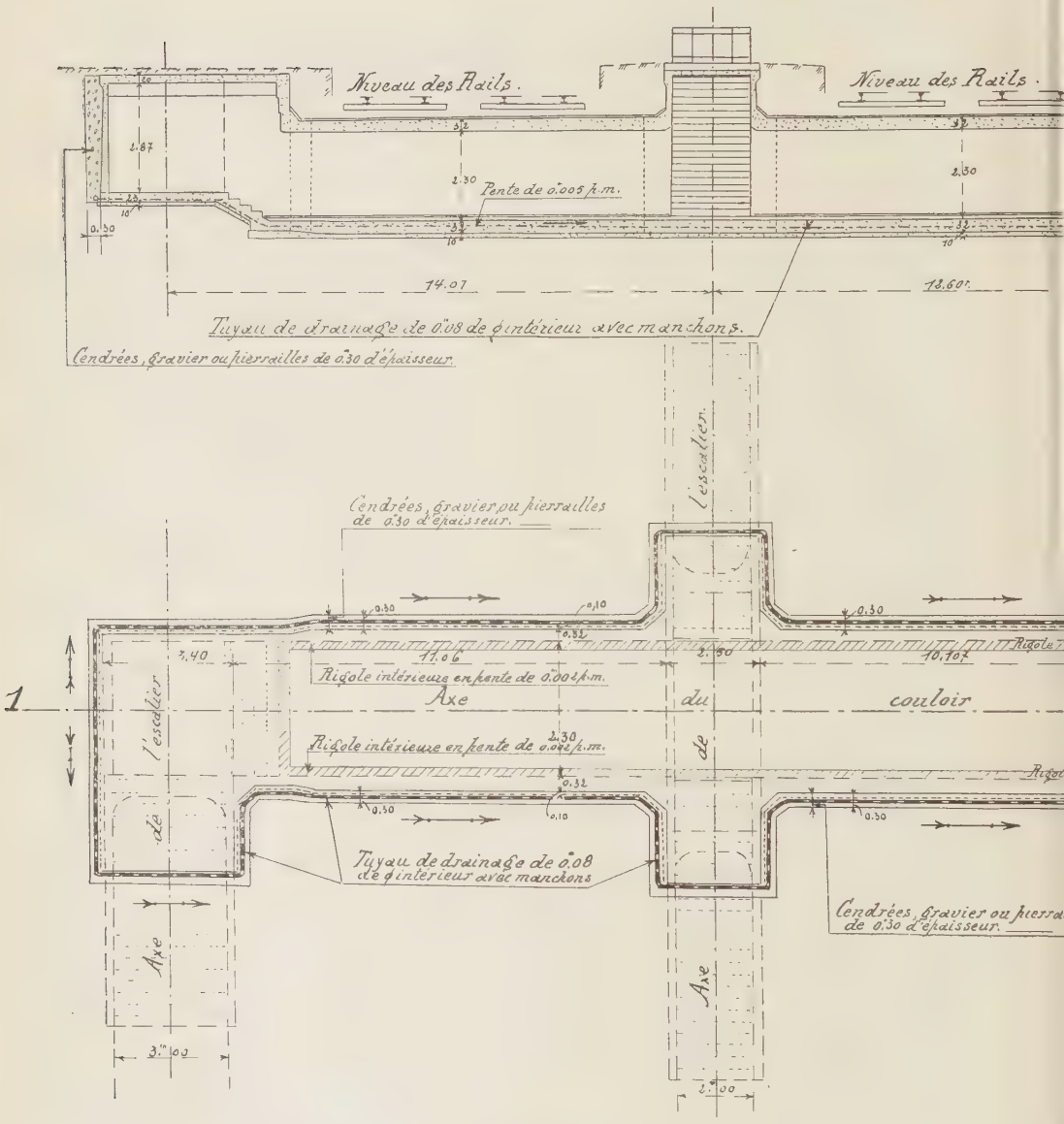
The water level would then always be kept below the floor level of the subway and there would be no danger of water percolating therein. It would perhaps be possible to have the constructional work carried out so as to ensure the concrete itself being watertight, but the precautions required would increase the cost considerably (keeping a low water level by pumping during the work, thoroughly good and rigid shuttering with perfect joints, and special care in making joints in the concrete).

The application of an outside sealing coat with proper drainage of the ground is undoubtedly the more economical method.

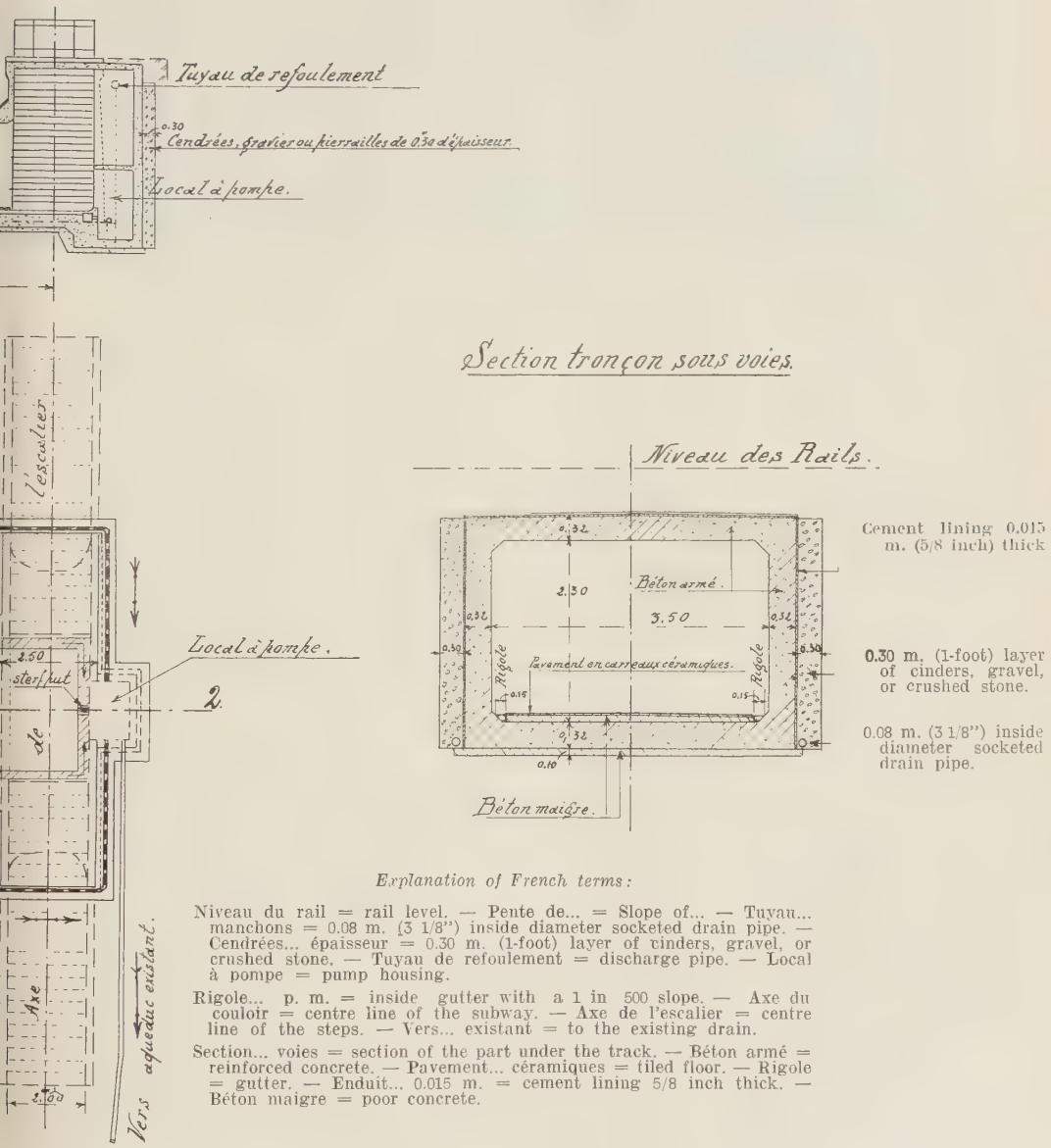
The drawings show sections through a subway built on the above principles.

The method is not applicable to subways in water-bearing strata; in this case a watertight casing must be constructed round the subway.

Longitudinal section along 1-2.


Niveau des Rails.
Niveau des Rails.
Pente de 0.005 p.m.
14.07
12.60
Tuyau de drainage de 0.08 de ø intérieur avec manchons.
Cendrées, gravier ou pierrailles de 0.30 d'épaisseur
Cendrées, gravier ou pierrailles de 0.30 d'épaisseur.
l'escalier
Rigole intérieure en pente de 0.004 p.m.
Axe du couloir
Rigole intérieure en pente de 0.004 p.m.
Tuyau de drainage de 0.08 de ø intérieur avec manchons
Cendrées, gravier ou pierrailles de 0.30 d'épaisseur.
Axe de l'escalier
Axe
1
2

Plan view of the drain.



Explanation of French terms:

Niveau du rail = rail level. — Pente de... = Slope of... — Tuyau... manchons = 0.08 m. (3 1/8") inside diameter socketed drain pipe. — Cendrées... épaisseur = 0.30 m. (1-foot) layer of cinders, gravel, or crushed stone. — Tuyau de refoulement = discharge pipe. — Local à pompe = pump housing.

Rigole... p. m. = inside gutter with a 1 in 500 slope. — Axe du couloir = centre line of the subway. — Axe de l'escalier = centre line of the steps. — Vers... existant = to the existing drain.

Section... voies = section of the part under the track. — Béton armé = reinforced concrete. — Pavement... céramiques = tiled floor. — Rigole = gutter. — Enduit... 0.015 m. = cement lining 5/8 inch thick. — Béton maigre = poor concrete.

[621. 132.5 (.73)]

New express locomotives of the Baltimore and Ohio Railroad.

(From *Die Lokomotive*, Vienna.)

The general tendency towards higher train speeds has led this railway to build two new types of locomotives for experimental purposes, in its Mount Clare shops, at Baltimore.

We have to thank Mr. Emerson, the Superintendent of Motive Power, for his kindness in enabling us to illustrate these two locomotives.

Figure 1 shows the 4-4-4 locomotive « Lady Baltimore », probably the first in America with this wheel arrangement, the use of which has not got beyond the experimental stage in Europe. Its chief feature is the boiler with Emerson type water-tube firebox, the pressure being 24.5 kgr./cm² (350 lb. per sq. in.) In order to reduce the air resistance as much as possible the overall height of the engine has been kept low, in spite of the 2.135 m. (7 ft.) diameter driving wheels. The centre line of the boiler is 2.77 m. (9 ft. 1 in.) above rail level, the barrel diameter is 1.574 m. (5 ft. 2 in.) and the length between tube plates is 5.413 m. (17 ft. 9 in.). Starting from the back end, the 2.998 m. (9 ft. 6 in.) long grate is 1.980 m. (6 ft. 6 in.) wide; the brick arch is over the leading pair of wheels of the trailing bogie and is followed by a combustion chamber 914 mm. (3 ft.) long extended to the front water chamber. The firebox casing 914 mm. (3 ft.) wide is then connected to the barrel; it encloses the 146 curved water tubes of 57 mm. (2 1/4 in.) outside diameter, forming the side walls of the firebox; these tubes are expanded into the bottom water drums.

The Emerson type superheater is fitted in 18 flue tubes 140 mm. (5 1/2 in.) outside diameter; its superheating surface, 32.5 m² (415 sq. ft.) is on the small side so that the superheat cannot be raised very high, and this, in conjunction with the high steam pressure, is a disadvantage. As the water tube firebox has 48.5 m² (523 sq. ft.) heating surface, the Baltimore & Ohio Railroad expects an evaporation of 13 t. or 270 kgr. per sq. m. (55.3 lb. per sq. ft.) of heating surface, and from the much greater tube heating surface, 116 m² (1 257 sq. ft.), only 5.7 t. or 49 kgr./m² (10.04 lb. per sq. ft.). The total evaporation of 18.7 t. is equivalent to an average of 114 kgr./m² (22.35 lb. per sq. ft.) for the 164.5 m² (1 780 sq. ft.) of heating surface or double what is usually expected in Germany, and neighbouring countries.

As is known, the Reichsbahn expects 57 kgr./m² (11.67 lb. per sq. ft.) per hour from ordinary boilers of about 330 m² (3 550 sq. ft.) heating surface with a ratio of grate area to heating surface of 1 to 60. The cylinder horse-power being estimated at 2 100, the work required of the grate would only be 365 kgr./m² (73.8 lb. per sq. ft.), while the production from the total heating surface would be 1.28 kgr./m² (26.2 lb. per sq. ft.). The railway company uses a cylinder horse-power of 1 810, a value probably selected for timetable purposes, as the peak horse-power is undoubtedly much higher. The high boiler pressure has made it possible, in conjunction with a long stroke, to use the very small cylinder diameter of 445 mm. (17 1/2 in.). At 80 % of the boiler pressure of

Fig. 1. — 4-4-4 express locomotive of the Baltimore & Ohio Railroad, built in the Mount Clare, Baltimore, shops of the Company, in September 1934.

Engine :		
Cylinders—diameter	445 mm.	*(17 1/2 in.)*
— stroke	711 mm.	*(28 in.)*
Wheel diameter—carrying	914 mm.	*(3 ft. 0 in.)*
— coupled	2 134 mm.	*(7 ft. 0 in.)*
Wheel base—leading bogie	2 032 mm.	*(6 ft. 8 in.)*
— rigid	2 252 mm.	*(7 ft. 5 in.)*
— trailing bogie	2 134 mm.	*(7 ft. 0 in.)*
— total	10 804 mm.	*(35 ft. 5 1/2 in.)*
Height of boiler centre line above rail	2 770 mm.	*(9 ft. 1 in.)*
Boiler diameter	1 574 mm.	*(5 ft. 2 in.)*
18 flue tubes—outside diameter	140 mm.	*(5 1/2 in.)*
77 smoke tubes—outside diameter	57 mm.	*(2 1/4 in.)*
Length over tube plates	5 413 mm.	*(17 ft. 9 in.)*
Boiler pressure	24.5 kgr./cm²	*(350 lb. per sq. in.)*
Heating surface—firebox	48.5 m²	*(523 sq. ft.)*
tubes and flues	116.0 m²	*(1 257 sq. ft.)*
total evaporative	164.5 m²	*(1 780 sq. ft.)*
superheating	32.5 m²	*(415 sq. ft.)*
total	197.0 m²	*(2 195 sq. ft.)*
Grate area	5.57 m²	*(61.75 sq. ft.)*
Weight, in working order—total	99.4 t.	*(217 800 lb.)*
adhesive	44.9 t.	*(99 800 lb.)*
Weight on 1st pair of wheels	9.0 t.	*(20 000 lb.)*
Weight on 2nd pair of wheels	9.0 t.	*(20 000 lb.)*
Weight on 3rd pair of wheels	22.3 t.	*(49 100 lb.)*
Weight on 4th pair of wheels	22.6 t.	*(49 700 lb.)*
Weight on 5th pair of wheels	16.8 t.	*(37 000 lb.)*
Weight on 6th pair of wheels	18.7 t.	*(41 000 lb.)*
Total length overall	14 205 mm.	*(46 ft. 7 1/4 in.)*
Width overall	3 126 mm.	*(10 ft. 3 in.)*
Height overall	4 080 mm.	*(13 ft. 4 1/2 in.)*
Tractive effort—engine	12.6 t.	*(28 000 lb.)*
booster	3.2 t.	*(7 000 lb.)*
total	15.8 t.	*(35 000 lb.)*
Tender :		
Diameter of wheels	914 mm.	*(3 ft. 0 in.)*
Wheel base—bogie	1 880 mm.	*(6 ft. 2 in.)*
total	6 710 mm.	*(22 ft. 0 in.)*
Water capacity	30.2 t.	*(6 630 Br. gall.)*
Coal capacity	12.6 tons.	
Weight empty	34.2 t.	*(75 400 lb.)*
Weight in running order	77.0 t.	*(170 000 lb.)*
Locomotive :		
Wheel base	21 750 mm.	*(71 ft. 4 in.)*
Length over buffers	25 200 mm.	*(82 ft. 8 in.)*
Weight in running order	175.4 t.	*(387 800 lb.)*

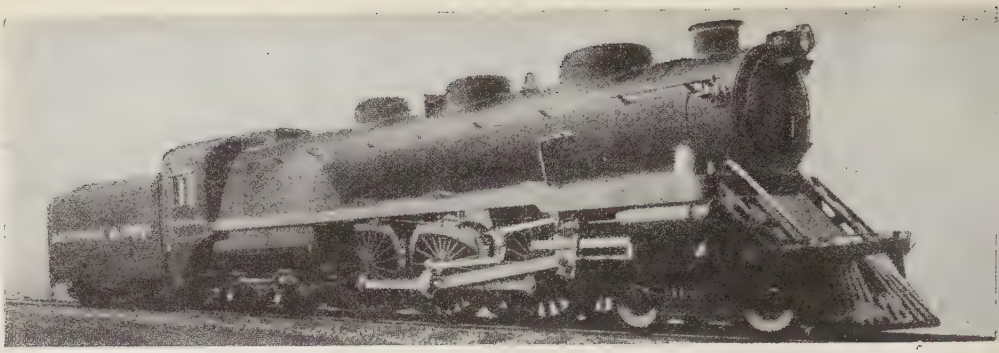


Fig. 2. — 4-6-4 express locomotive of the Baltimore and Ohio Railroad, built in January 1935 in the Company's Mount Clare shops, Baltimore.

Engine :		
Cylinders—diameter	483 mm.	*(19 in.)*
— stroke	711 mm.	*(28 in.)*
Wheel diameter—carrying	914 mm.	*(3 ft. 0 in.)*
— coupled	2 134 mm.	*(7 ft. 0 in.)*
Wheel base—leading bogie	2 032 mm.	*(6 ft. 8 in.)*
— rigid	4 522 mm.	*(14 ft. 10 in.)*
— trailing bogie	2 135 mm.	*(7 ft. 0 in.)*
— total	13 077 mm.	*(42 ft. 11 in.)*
Height of boiler centre line above rail	2 952 mm.	*(9 ft. 8 1/4 in.)*
Boiler diameter	1 829 mm.	*(6 ft. 0 in.)*
27 flue tubes—outside diameter	140 mm.	*(5 1/2 in.)*
120 smoke tubes—outside diameter	57 mm.	*(2 1/4 in.)*
Length over tube plates	7 625 mm.	*(25 ft. 0 in.)*
Boiler pressure	24.5 kgr./cm²	*(350 lb. per sq. in.)*
Heating surface—firebox	57 m²	*(612 sq. ft.)*
tubes and flues	254 m²	*(2 727 sq. ft.)*
total evaporative	311 m²	*(3 339 sq. ft.)*
superheating	67 m²	*(880 sq. ft.)*
total	378 m²	*(4 219 sq. ft.)*
Grate area	5.72 m²	*(61.75 sq. ft.)*
Weight in working order—total	133.5 t.	*(294 000 lb.)*
adhesive	70.9 t.	*(156 000 lb.)*
Weight on 1st pair of wheels	10.2 t.	*(22 500 lb.)*
Weight on 2nd pair of wheels	10.2 t.	*(22 500 lb.)*
Weight on 3rd pair of wheels	23.2 t.	*(51 000 lb.)*
Weight on 4th pair of wheels	24.5 t.	*(54 000 lb.)*
Weight on 5th pair of wheels	23.2 t.	*(51 000 lb.)*
Weight on 6th pair of wheels	20.4 t.	*(45 000 lb.)*
Weight on 7th pair of wheels	21.8 t.	*(48 000 lb.)*
Total length overall	18 094 mm.	*(59 ft. 4 1/2 in.)*
Width overall	3 080 mm.	*(10 ft. 1 1/4 in.)*
Height overall	4 395 mm.	*(14 ft. 4 3/4 in.)*
Tractive effort—engine	15.2 t.	*(34 000 lb.)*
booster	3.4 t.	*(7 000 lb.)*
total	18.6 t.	*(41 000 lb.)*
Tender :		
Diameter of wheels	914 mm.	*(3 ft. 0 in.)*
Wheel base—bogie	1 880 mm.	*(6 ft. 2 in.)*
total	7 269 mm.	*(23 ft. 10 in.)*
Water capacity	37.85 t.	*(8 325 Br. gall.)*
Coal capacity	14.45 tons	
Weight empty	37.70 t.	*(83 000 lb.)*
Weight in working order	90.00 t.	*(199 800 lb.)*
Locomotive :		
Wheel base	24 857 mm.	*(81 ft. 7 in.)*
Length over buffers	28 320 mm.	*(92 ft. 11 in.)*
Weight in working order	223.5 t.	*(493 800 lb.)*

24.5 kgr. (350 lb. per sq. in.) the tractive effort is 12 600 kgr. (28 000 lb.), equivalent to a factor of adhesion of 3.5. The connecting rods are 3.30 m. (10 ft. 6 in.) long with the same I section the full length. The crosshead is carried under the slide bars which are closed in on the outside. Tail rods are not fitted to the piston rods nor to the valve spindle rods.

The Walschaerts gear is very light and drives 254 mm. (10 in.) diameter inside admission piston valves. Compressed-air reversing gear and mechanical lubrication are fitted. A booster is fitted on the back axle of the carrying bogie and increases the starting effort from 12 600 to 15 800 kgr. (28 000 lb. to 35 000 lb.). The axle load is particularly low for American practice, but is ample for the high speeds and light train loads (about 250 long tons) in question. The driving wheel journals are 254 mm. (10 in.) in diameter by 280 mm. (11 1/32 in.) long, which should be quite sufficient.

All the bogie wheels are solid-centre wheels 914 mm. (3 ft.) in diameter. The leading bogie has outside frames and the trailing, inside. The wheel bases are 2.032 m. and 2.134 m. (6 ft. 8 in. and 7 ft.) respectively. The journals are 165 × 305 mm. (6 1/2 in. × 12 in.) on the leading bogie, and 178 × 330 mm. (7 in. × 13 in.) on the trailing bogie, to correspond with the different axle loads of 9 and 17 tons.

The brake acts on all wheels, each wheel having a single block. The horizontal compressor is carried on the tender. The coupled wheels are sanded in forward running and the driving wheels in reverse running. The cab is kept as low as possible and is completely shut in, as in Canada. As in England the chimney top is polished copper or brass, and the boiler casing is free from projections. The aerodynamic form in vogue elsewhere has not been adopted, although inclined plates are fitted between the footplate and the barrel. The motion and running gear are not covered in.

The 8-wheeled tender follows the contour of the cab very closely. The short wheel-base bogies have the same wheel diameter of 914 mm. (3 ft.) as that of the engine bogie wheels, but with smaller journals, 152 × 280 mm. (6 in. × 11 in.), although the load is the same.

Roller bearing axle boxes are fitted. The water capacity, 30 m³ (6 630 Br. gallons), must be considered rather small, especially with the 12 tons of coal, the more so that a mechanical stoker is fitted.

The first locomotive « Lady Baltimore », No. 21, Class J 1, was built in the Company's shop and put into service in September 1934. It is painted blue like the aluminium coaches of the train. In test runs on different lines of the railway, a speed of 152 km. (95 miles) an hour was reached, and 1 570 H.P. developed. A water trough has been laid down on the long stretch along the Atlantic seaboard following Pennsylvania Railroad practice.

In January 1935, the Company completed a 4-6-4 locomotive named « Lord Baltimore » No. 2, Class V 2. It is developed from the preceding locomotive by adding a trailing pair of coupled wheels. The two bogies are interchangeable with those of the « Lady Baltimore ». The water tube firebox, the boiler pressure and grate area are all the same. The barrel diameter has been markedly increased, from 1.574 m. (5 ft. 2 in.) to 1.829 m. (6 ft.), and the boiler centre line raised to 2 952 m. (9 ft. 8 1/4 in.).

The length of the boiler has been increased by almost the diameter of the coupled wheels, i.e. by 2.312 m. (7 ft. 7 in.). The superheater has been increased considerably, and with 27 flues instead of 18, its heating surface has been nearly doubled. The increase in the boiler diameter raised the height of

the firebox, and increased its heating surface, and its evaporation from 13.2 tons to 15.4 tons with a total steam production of 25.2 tons instead of 18.7. This increase of 35 % has to be set against a 57 % increase in adhesive weight which means that the engine will make little use of its high adhesive weight of 70 tons. The trailing bogie is also booster-fitted, the additional tractive effort also being 3 200 kgr. (7 000 lb.). The large steam cylinders exert a maximum thrust of 45 tons and the journals have been made 280 mm. (11 1/32 in.) in diameter. Their length, 330 mm. (13 in.), is the same, as is the diameter of the coupled wheels, which have not been changed. The tyres are 102 mm. (4 in.) thick. The fittings are the same as on the 4-4-4 : mechanical stoker, compressed-air reversing gear, turbo-generator, brake compressor on tender, and roller bearings. The larger and higher tender has a greater capacity. The Company gives the maximum cylinder horsepower of the engine as 2 200 which equals 380 H.P. per sq. m. (36.2 H.P. per sq. ft.) of grate; with the hourly evaporation quoted above, 25.2 tons, the steam consumption is 11.4 kgr. (25 lb.). As a comparison the 2C2 class 05 Reichsbahn locomotive of the same weight develops with 15 tons of steam, 2 800 H.P. at speeds as high as 192 km. (119.3 miles) an hour.

[621. 335 (.73)]

GG1 type electric passenger locomotives, Pennsylvania Railroad.

(Railway Age.)

All through passenger and freight service on the Pennsylvania between New York and Washington, D. C., and west as far as Paoli, Pa., is now handled electrically, except for certain branch line or connecting trains which require steam locomotives over a considerable part of their run, and on which change of power would not be economical.

Electric operation of main line trains between New York and Philadelphia was begun on January 16, 1933, and was followed shortly by electric operation from New York to Wilmington, Del., and Paoli, Pa. During the first year of electric operation, the electric locomotives handling this service covered 4 647 934 locomotive miles, and their operation was subjected to a comprehensive study by the railroad company, not only as to performance but also as to obtain additional information for the analysis of electrically-operated passenger and freight schedules.

The original program contemplated building 28 additional passenger locomotives of the same type as those already in use on passenger trains for the extension of the passenger service from Wilmington to Washington, D. C., and parts of these locomotives had been constructed and stored at the works of the manufacturers. Sixty locomotives for freight service only were contemplated and one of these was built and placed in service during 1933, in addition to two experimental locomotives of similar type built in 1932. Experience indicated that better freight operation could be secured by the use of more powerful and higher-speed locomotives than the three experimental freight locomotives, and also that the

requirements of passenger service were such as to make desirable the use of more powerful and faster passenger locomotives than those then in use for the through service from New York to Philadelphia, Wilmington and Paoli.

It was, therefore, decided to transfer to the freight service 59 of the passenger locomotives already operating between New York and Wilmington, and to substitute in their place 59 locomotives of improved design, and by so doing to secure in both the passenger and freight service the benefit of higher speed and more powerful locomotives than were contemplated in the original program. The arrangement also provided the advantage of having a large number of locomotives in freight service, available also for high-speed passenger service, thus obtaining increased flexibility of operation.

In December, 1933, arrangements were completed with the Public Works Administration for financing the continuation of the electrification program. Immediate steps were taken to redesign and complete the 28 passenger locomotives of the older design (already partially constructed), and to design and construct 59 new passenger locomotives. The problem of locomotive design was undertaken by a committee of engineers, including representatives of the General Electric Company, the Westinghouse Electric & Manufacturing Company, the Baldwin Locomotive Works and the railroad's mechanical and electrical departments. Five general requirements of design for new locomotives were laid down by the railroad, as follows :

(1) The locomotive must be suitable for operation at 100 m.p.h. or more;

(2) it must have a capacity of approximately 4 500 h.p.;

(3) the weight of each driving axle must not greatly exceed 55 000 lb.;

(4) the operating cab must be near the central part of the locomotive, and

(5) the locomotive must be pleasing in appearance.

General designs of two types of locomotive were worked out and detailing started early in 1934. The two locomotives were given the type numbers R1 and GG1, and consisted, respectively, of locomotives having a 4-8-4 and a 4-6 + 6-4 wheel arrangement. The four driving axles on the R1 were arranged in a rigid wheel base, while the GG1 consisted of two 4-6-0 frames connected back-to-back by an articulated joint under a single cab. Sample locomotives of both these types were completed by September, 1934. When these were received, the services of an expert were engaged to make the locomotive design as pleasing as possible. They were equipped with testing apparatus and comparative tests were run for a period of two months. By December, 1934, the test results, together with various factors of first cost, maintenance, etc., had been analyzed. Each type had many points in its favor, but the GG1 was chosen after all factors were considered. The construction of 57 additional units of this type was started immediately. The first was finished in April and the last by August 3 of 1935.

Fourteen locomotives were built at the General Electric plant at Erie, Pa., 18 in the railroad shops at Altoona, Pa., and 25 were assembled at Altoona on chassis built at the Baldwin Locomotive Works.

General characteristics.

The type GG1 locomotives consist of a streamlined cab supported on two cast-steel main frames, each with three driving axles and a two-axle guiding truck at one end. The cab consists of a central portion with a hood of reduced section at either end and rests on center plates and spring pads on the two main frames. Cab longitudinal strength is provided by two trusses framed into the cab and extending between center plates. The cab frame structure is mostly riveted but the

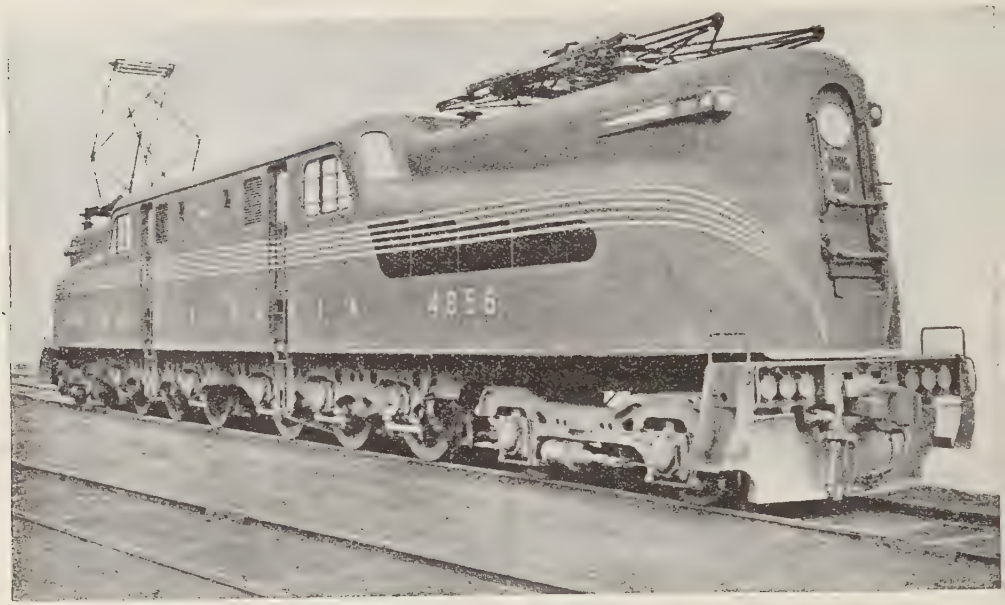


Fig. 1. — General view.

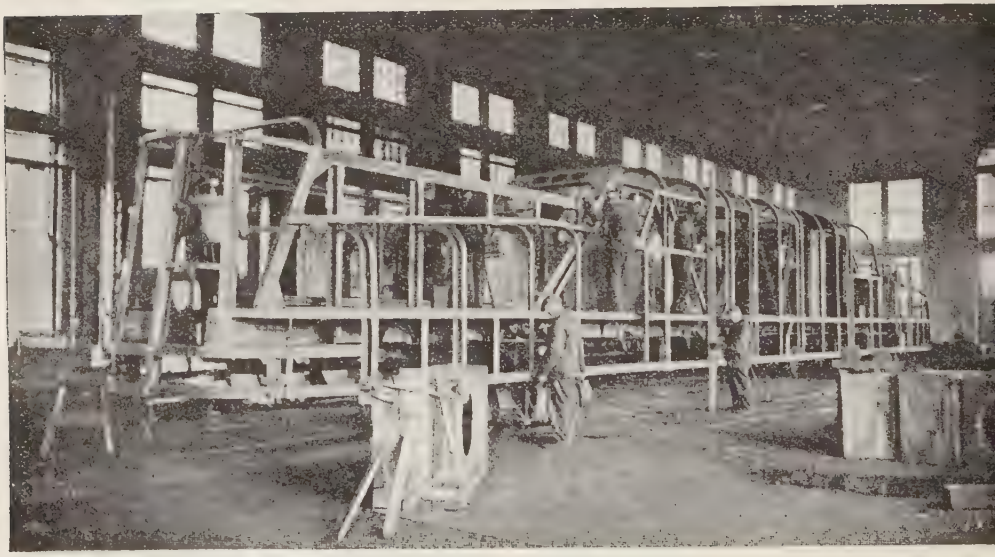


Fig. 2. — Cab frame.

side and roof sheets are welded. The joints of the cab sheets are butted edge to edge, welded and ground, making a smooth exterior without rivet heads. The cab is formed in sweeping contours; striping is used to emphasize its smooth, unbroken surface. The side doors and windows are recessed and marker light projections are carefully streamlined.

To further improve the appearance of the locomotive, butt straps and belt rails were eliminated, the front steps were sloped back and the lower edge of the cab sheets rolled inward. The ladders for reaching the pantographs were placed inside so that access to the roof is through hatches, these being interlocked with the pantograph grounding switches. One pantograph insulator was placed on top of another to eliminate the usual sub-base, and at the same time to provide double insulation. The bell was hung under the cab near one end. These and numerous other details serve to give the locomotive a clean, streamlined appearance when connected to the train, even though it is required to operate in either direction. The particular kind of striping selected in effect gives length to the locomotive and reduces its height.

An oil-fired train heating boiler, air compressor, and the transformer with its allied switching apparatus, are located at the center of the locomotive. Also in the center section are two operating compartments for the crew. The two hoods contain the ventilating blowers, oil and water tanks, with a pantograph mounted on top of each. End doors furnish access between locomotives when double-headed. The four end cab windows are equipped with window wipers, and are hinged to permit cleaning from within the cab.

Running gear.

Each of the six driving axles is driven by a twin motor through a quill drive. The two motor pinions mesh with a single spur gear (gear ratio 22 : 79) mounted at one end of a quill which surrounds the axle. A spider at each end of the quill transmits the drive through spring cups and wearing plates which allow for movement between the quill, which is carried in bearings in the twin-motor, and the axle. Quill bearings are of the split-sleeve type, with constant oil level wick lubrication. Roller bearings are used for all traction motor armatures and for driving and truck journals on all but six locomotives, which are equipped with plain journal bearings. The equivalent of a 6 1/2-in. by 12-in. journal is used for the driving boxes and of a 6-in. by 11-in. journal for the truck boxes. The three driving axles on each side of a main frame are equalized. Each of these systems, together with the guiding truck support, constitutes a 3-point suspension. The main frames of the locomotive are articulated, their inner ends being connected by a ball and socket type joint. On curved track, the main frames form an angle with each other and with the cab, but on tangent track a force tending to hold them in alinement is provided by a restraining device. This consists of a pair of rollers mounted on the cab structure, which are forced by spring action into notches on a frame-mounted member when the two frames are in line, but which lift out of the notches when on curves. One of the two center plate supports for the cab is designed to allow for longitudinal movement between the cab and the frame. The cab side bearings (four in number) each consist of a spring plunger arrangement in which there are nests of springs. They are located between the two inside main driving axles on each frame and support a part of the weight of the cab.

The guiding trucks have cast-steel frames. The truck wheel diameters are 36 in. and the wheel base 8 ft. In addition to the rocker suspension which pro-

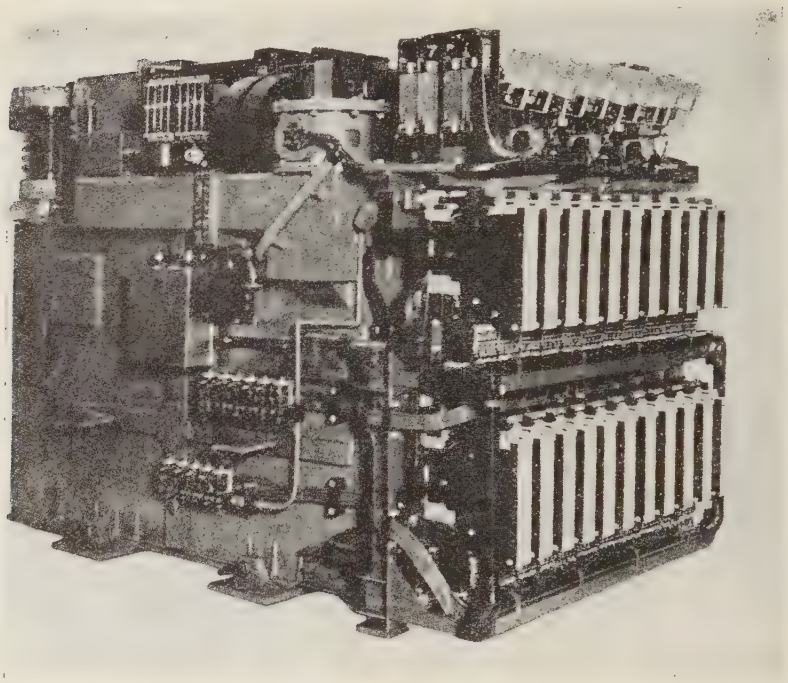


Fig. 3. — Transformer and switch group.

vides for a graduated side thrust, the trucks are also equipped with a restraint arrangement which controls swiveling action. This consists of a spring device on the locomotive frame, connected by links to a tail bar on the truck.

Transformer.

The 11 000-volt power from the trolley is collected by either of two pantographs, connected by a high-voltage bus arranged for the isolation of either collector in case of damage. Substation breakers are relied upon to disconnect a section of the trolley in case of major electrical trouble on the locomotive. An oil-cooled transformer was selected to replace the air-cooled unit on the first GG1. This change has eliminated all difficulties caused by snow or moisture and provides increased insulation resistance and correspondingly greater protection against lightning surges.

Both forced oil and air are employed for cooling, a method which has proved so efficient that the complete unit is only slightly heavier than the conventional dry, air-blast type. The transformer steps down the trolley voltage through a series of taps in the secondary to the motors. Auxiliary apparatus, including the motor contactors, is mounted on top and at one end of the transformer tank. The rating of the transformer is 4 800 kva., with a ratio of 11 000 : 408 volts at 25 cycles. The total weight of the assembled unit is 34 300 lb., including 9 300 lb. of auxiliary apparatus. A corresponding air-blast transformer weighs 33 800 lb.

Fig. 4. — Running gear.

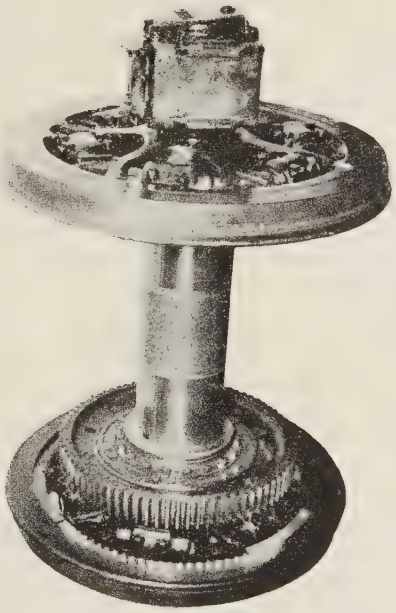


Fig. 6. — Pair of driving wheels with quill.

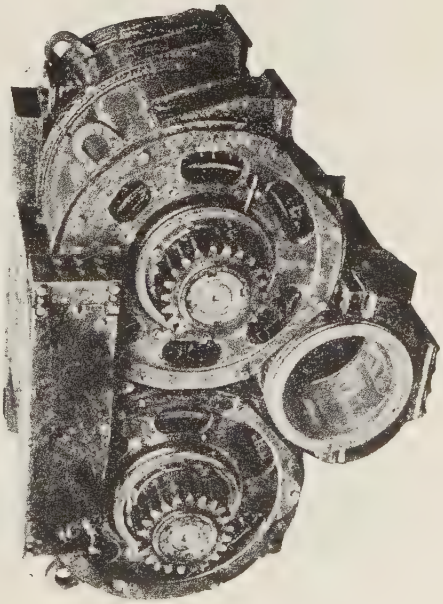


Fig. 5. — One of the twin motors.

Motors.

The twin motors each consist of two armatures carried in a single fabricated frame, with the driving pinions meshing in a single solid gear carried on the quill. A three-point suspension is used for these motors, with provision for adjustment to maintain the quills central with the axle. A fabricated gear case, split horizontally into two parts through the gear center, covers the gear and pinions.

In construction, two rolled steel barrels are used to form the motor frames. These are combined with other parts, making a total of 126 pieces, welded into each double frame. After welding, the frame is strain-relieved, and is then ready for machining. This design provides for a minimum of weight and space and a maximum of strength.

The motors are force-ventilated, the ventilating air being taken from ducts fabricated into the cab framing. The air is passed into the commutator chambers, passes over the armature and stator windings and is exhausted through frame openings at the pinion ends. The stator and its armatures are ventilated in multiple. The armatures are multiple-wound and the 12-pole laminated stators have partially open slots. They have commutating poles with the commutating, compensating and exciting field windings all connected in series. Two commutating field strengths are employed to provide practically back commutation, at all motor speeds. The stators are wound with continuous coils, mica-insulated, and the coils of each winding are connected in multiple. This is accomplished by silver soldering the ends of the several coils to mica-insulated box rings.

The weight of the motor is 14 500 lb. The normal operating voltage is 230-300 volts per armature, or 460-600 volts per twin motor. The motors are connected permanently in three parallel circuits, with four single motors in series in each circuit. Based on actual experience with P5a and results up to date on GG1, it is expected that GG1 locomotives will run 250 000 miles between commutator turnings, and that one set of brushes will last more than 100 000 miles.

Control.

The control for the locomotives consists of a master controller which operates individual electro-pneumatic contactors, tapping the secondary winding of the transformer. There are 11 taps on the transformer secondary, allowing for 22 notches on the controller, with preventive coils used to avoid short-circuiting a section of the secondary windings during tap changing. The preventive coil reactance limits current surges during transition from one notch to another.

The number of notches are in effect trebled by the use of what is called a « notching transformer ». The secondary of this transformer is in series with the main motor circuit and normally bucks or opposes the motor voltage by 16 volts. Raising the controller handle slightly, without moving it horizontally from one notch to another, operates contactors which eliminate the opposing voltage. Returning the controller handle to its lower position causes the notching transformer to boost the motor voltage by 16 volts. When the controller handle is moved to the next notch, the notching transformer again opposes the motor voltage. This device is used primarily for making heavy starts. The controller is also equipped with a dead man's handle which, if released, cuts off power to the motors and causes a brake application.

On an instrument panel above the controller are three ammeters, one for each motor circuit, a speedometer (reading in miles per hour) and two air gages. Five indicating lights at the left of the panel are used to show, respectively, low wa-

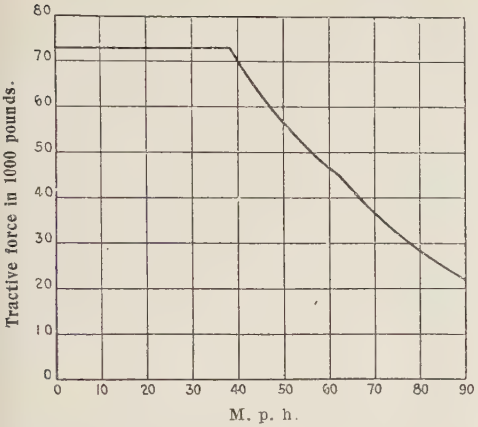


Fig. 7. — Locomotive speed-tractive effort curve.

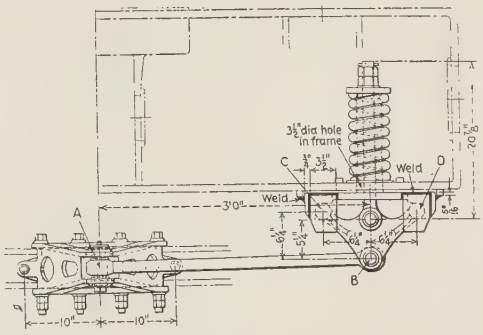
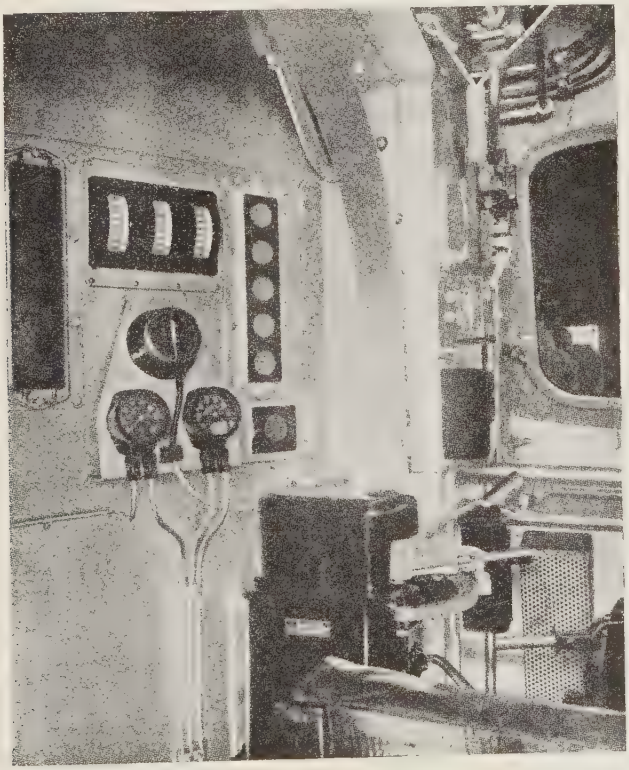


Fig. 8. — Guiding truck restraint mechanism.



One of the control positions.

ter in boiler, blower or oil pump stopped, overload tripped, drivers slipping, and pantograph relay tripped. A buzzer calls the engineman's attention to these lights in case one of them operates.

Protection against overspeeding when a pair of wheels slip is furnished by a relay which operates when the speed differential between any pair of drivers becomes greater than eight miles an hour. This causes the indicating light to show and the buzzer to operate. If the warning is not heeded, and the differential becomes greater than 20 m.p.h., all motor switches are automatically opened.

For protection against faults in the locomotive circuits there is a pantograph relay which starts to operate and gives a light indication if there is a fault on some piece of secondary apparatus or the primary winding of the main transformer. The relay, in progressing from its initial to its final position, opens the auxiliary contactors and the main motor contactors. If the fault is removed in this process, the relay returns to its initial position and the contacts may be reset electrically from the engineman's position. It the fault is not removed, the relay continues to its final position, at which point it causes a grounding switch to close, grounding the pantograph and trolley wire; this results in the high-speed substation breakers disconnecting the section of trolley which serves the locomotive. After the line is dead the relay automatically lowers and locks down the pantograph. The relay will operate in case of a transformer secondary ground or secondary overload, primary overload or primary ground.

An indicating light at the lower right-hand corner of the control panel is labeled « field changeover », and indicates that connections of the shunt across the motor main fields, which is used at starting, have changed.

The locomotives are equipped with cab signals. Miniature position-light signals at the right of the control panel show clear, approach, restricting, approach, and caution slow speed.

General specifications for the type GG1 passenger locomotives.

Length—coupler faces	79 ft. 6 in.
Width—cab	10 ft. 4 3/16 in.
Height—pantograph down	15 ft. 0 in.
Height—pantograph up	Max. wire height, 25 ft. 6 in.; Panto. free height 26 ft. 0 in.
Total wheel base	69 ft. 0 in.
Rigid wheel base	13 ft. 8 in.
Truck wheel base	8 ft. 0 in.
Weight—total	460 000.
Weight on drivers	300 000.
Weight on truck	80 000.
Weight per driving axle	50 000.
Diam. driving wheels	57 in.
Diam. truck wheels	36 in.
Driving axle bearing size	6 1/2 in. by 12 in.
Truck axle bearing size	6 in. by 11 in.
Locomotive H.P. continuous	4 620 at 90 m.p.h.
Locomotive H.P. max.—(short time)	7 000.
Maximum tractive effort	72 800.
Continuous maximum speed as geared	90 m.p.h.
Efficiency—per cent	Start { 80 } Run { 80 }
Power factor—per cent	Start { 80 } Run { 97 }
Number of motors	6—twin motors ; 12 armatures.
H.P. each armature	385.
Motor voltage	4 armatures in series—368 to 1 328.

Gear ratio	22:79.
Line voltage	11 000.
Air compressor	Vertical, 150 c.f.m.
Blower motors	2—52 H.P. ind. motors
D.C. generator capacity	2 700 watts, 32 volts.
Generator drive	Generator mounted on one of blower motors.
Blowers	2 blowers.
Blower capacity, each	25 000 c.f.m. at 9.6-in. s. p. at fan outlet.
Blower motor voltage	480.
Comp. motor voltage	224 volts.
Battery	Lead—16 cells—300 a.h.
Control and lights	32 volts d.c.
Type of control	Electro-pneumatic.
Cab signal equipment	US & S Co. code system, four indications, with whistle and acknowledger.
Steam heating boiler	Altoona Works.
Capacity	4 500 lb. per hr. approx.
Control	Automatic.
Capacity sand boxes	3 000 lb.
Capacity oil tanks	3 000 lb. (400 gall.).
Capacity water tanks	22 700 lb. (2 720 gall.).

Auxiliary apparatus.

Cooling air for motors, transformers and other electrical apparatus is supplied by two motor-driven blowers, one under each of the end hoods. The blower motors are 52-H.P. 25-cycle-phase induction motors, operating at a speed of 1 450 r.p.m. One of them also drives a 2 700-watt D.C. generator which supplies power for the control circuits, for lighting and for charging the 16-cell 300-amp.-hr. storage battery. The battery is located in the end hood close to the generator.

The air compressor, which supplies air for brakes and the operation of control apparatus, is a motor-driven vertical unit, having a capacity of 150 cu. ft. per minute. The compressor motor is a 35-H.P. 224-volt single-phase commutator-type motor, operating at 1 200 r.p.m. There are two air brake cylinders at one end of each driving truck, which operate clasp brakes on the driving wheels. The engine truck has one outside-mounted brake cylinder on each side, with one brake shoe per wheel.

An oil-fired train heating boiler is located near the center of the cab between the two operating positions. The boiler is of the vertical tubular type, having an evaporating capacity of 4 500 lb. of water per hour, at 200 lb. pressure. These boilers, which were built at the Altoona shops of the Pennsylvania Railroad, are essentially the same as those used on the original P5 type locomotives.

Headlights are placed inside the end doors and project their light through circular openings near the top of the door. Combined marker light and illuminated numeral panel housings are supplied with a streamlined contour to conform with the lines of the locomotive. Hatches in the roof allow for the removal of transformer, heating boiler, blowers and air compressor. The pantographs will operate satisfactorily in tunnels at a height only 3 in. greater than the locked-down position. Ventilating ducts are formed into the cab frames, and sand boxes, water tanks and oil tanks are disposed along the inside of the hoods on each side. They are fabricated in a variety of shapes to conform with space requirements.

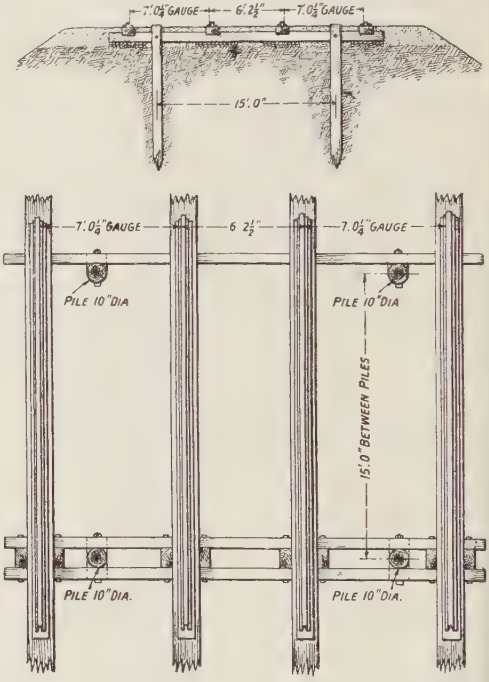
[625. 14 (09 (.42) & 656. 25 (09 (.42)]

Permanent way and signalling on the Great Western Railway (Gt. Bn.).

(*The Railway Gazette*, Great Western Centenary number).

There has probably never been anything more remarkable in railway engineering than the 7-ft. gauge of the original Great Western Railway, the first section of which was opened on June 4, 1838, between London and Maidenhead. In recommending the 7-ft. gauge, Brunel had in mind the attainment of higher speeds than were possible on a narrow gauge railway, combined with increased stability of the rolling stock. The consideration of speed was held to justify the expense of constructing a line with a ruling gradient of 1 in 1 320, but Brunel's original argument in favour of the 7-ft. gauge was that it would enable carriages to be built with the bodies slung between the wheels so having a lower centre of gravity than usual. The wheels moreover could be of large diameter, and this Brunel claimed would contribute to smoother running by reducing friction. No great stress was laid by Brunel upon the advantages of the more liberal dimensions to which locomotives and rolling stock could be built on the 7-ft. gauge (actually 7 ft. 0 1/4 in.).

The benefits of the broad gauge could be reaped only if the rails were laid on a satisfactory foundation, and it was to achieve this that Brunel designed his permanent way on longitudinal timbers with cross transoms fixed to piles, as shown in the accompanying sketch. The longitudinal members were of kyanised American pine 30 ft. in length, 12 in. to 14 in. wide, and 6 in. to 7 in. deep. The transoms, also of American pine, extended across the full width of both tracks and were spaced at intervals of 15 ft. and bolted to the longitudinals. Two of them thus fell together whenever the 30-ft. lengths of framing joined. The transoms were 6 in. broad and 9 in. deep in the single pattern, but 6 in. deep when double. On curves the transoms were

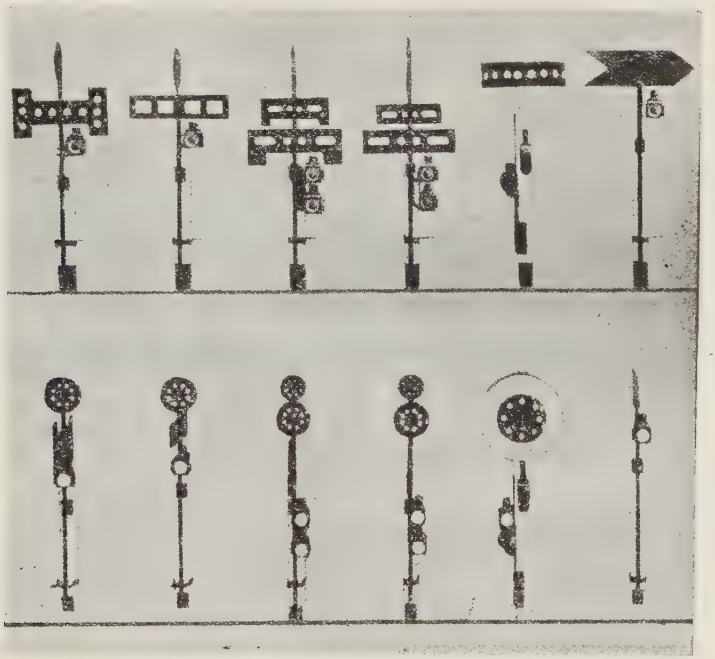


Section and plan of early Great Western Railway broad gauge track.

given an inward cant of 5 in. divided by the radius of the curve in miles. This was based upon a total width across both tracks of 20 ft. 3 in. and all curves were very flat. The transoms were housed into the piles to which they were bolted

The piles, which were 9 in. to 10 in. diameter, were driven into the ground between the running rails and were of beech. Their length varied according to circumstances. In cuttings they were from 8 ft. to 10 ft., but on embankments the lengths ran up to about 18 ft. When the construction of the framework was completed fine ballast was packed under the longitudinals. The upward stress imposed by this pressure was counteracted by the piles, the purpose of which was to hold the track down and not to give it support.

In a report to the directors on the progress of construction towards the end of 1837, Brunel wrote « the peculiarity of the plan which has been adopted, consists principally in two points; first, in the use of a light flat rail, secured to timber, and supported over its entire surface, instead of a deep heavy rail, supported only at intervals and depending on its own rigidity. Secondly, in the



Specimens of old Great Western Railway signals.

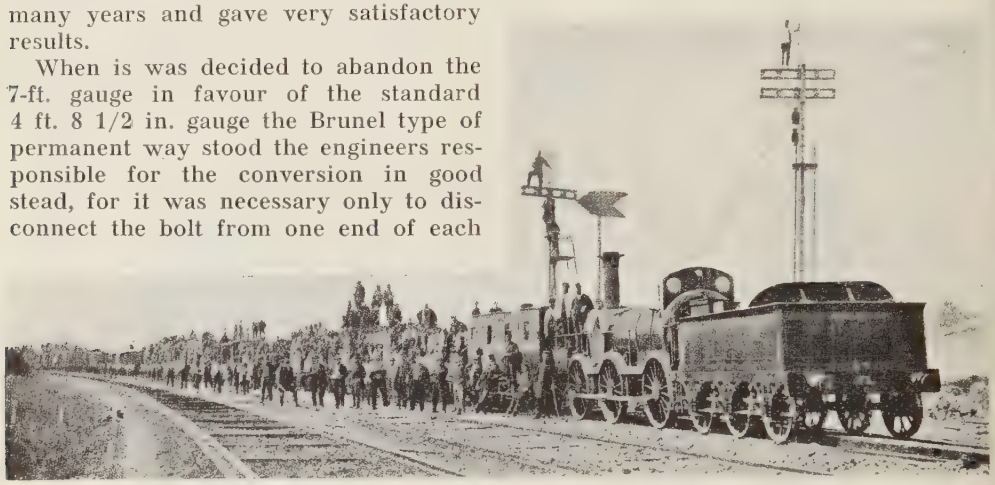
timbers which form the support of this rail being secured and held down to the ground, so that the hardness and degree of resistance of the surface upon which the timbers rest, may be increased by ramming to an almost unlimited extent. »

To give a cant of 1 in 20 to the rails, which were of the bridge pattern, weighed 43 lb. per yard, and were of lengths varying from 14 ft. to 17 ft., they were mounted on a tapered hardwood plank laid on top of the longitudinal timber. The flanges of the rails were bolted direct to the longitudinals.

It was soon found that in practice the piles did not fulfil their intended purpose. The packing under the longitudinals was soon driven downward leav-

ing the longitudinals unsupported except by the piles. That left the longitudinals more or less free to deflect between the piles giving rise to very unsteady running, and for this reason the piling was abandoned. Otherwise this type of permanent way was adopted as standard for many years and gave very satisfactory results.

When is was decided to abandon the 7-ft. gauge in favour of the standard 4 ft. 8 1/2 in. gauge the Brunel type of permanent way stood the engineers responsible for the conversion in good stead, for it was necessary only to disconnect the bolt from one end of each transom, saw off about 2 ft. 3 1/2 in. of the latter, and then slue the timber with the rail on it to the end of the shortened transoms and refix and screw up the bolts. The inner rails of double lines were, of course, those moved. Only



Gauge conversion staff train, from a photograph taken at Grange Court in May, 1872.

very little broad-gauge track was ever relayed on ordinary cross sleepers, although most of the standard gauge sections of the G. W. R. system were so laid originally. Brunel used the Barlow type of rail on the South Wales Railway and on the West Cornwall main line. The Barlow rail was of a section somewhat resembling that of a bird in flight, the head of the rail being the body and having two wide-spreading wings. It could thus be laid direct on the ballast without timbers or sleepers and the two rails were held to gauge by iron bars. Brunel's reason for using this type of rail on the West Cornwall line, which was originally laid to 4 ft. 8 1/2 in. gauge, was the ease with which it could be converted to 7 ft. gauge, an event which was early expected. The Barlow rail was not found satisfactory in service owing to its liability to fracture.

Long before the final conversion from broad to narrow gauge the inconvenience of the former led to the laying of considerable lengths of mixed gauge, and of main line only that west of Exeter remained entirely broad gauge in 1892, the date of the ultimate conversion. The first big conversion took place in May, 1872, on the whole of the line from Gloucester through South Wales with its branches, comprising altogether about 188 miles of double and 38 miles of single line, or a total of about 500 track miles, including sidings.

Among the outstanding features of Great Western permanent way, besides that of the broad gauge built to Brunel's design, may be mentioned the extensive use of steel sleepers in recent years, the universal adoption for many years of chair bolts instead of the R. E. A. standard coach-screw fastening, and a very

high standard of junction design and maintenance, which reduces to a minimum speed restrictions over diverging routes. The Great Western was one of the pioneers in the use of switch diamonds, making practicable the use of very easy turnouts for main-line junctions. For long the Great Western has been famous for speed, and the contribution of the permanent way to this end has been an important one.

Signalling.

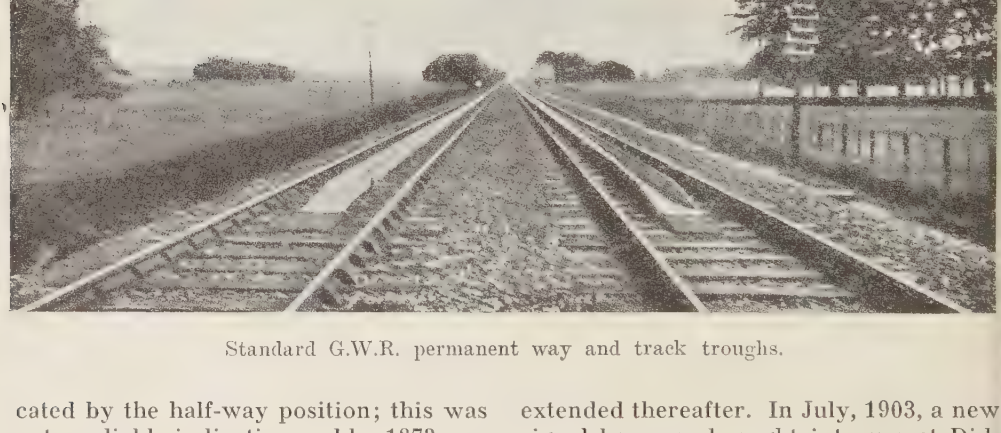
When the first section of the Great Western Railway was opened to Maidenhead in June, 1838, there were no fixed signals. It was thought that the company's police posted at the stations and level crossings, or patrolling their beats, into which the whole line was divided, would be able to control the traffic by hand signals in much the same way as road traffic is controlled. The first signal appears to have been one at Maidenhead, mentioned in a notice to the enginemen, signed by Seyr. Clarke, the Chief Superintendent, Paddington, July 26, 1839, and this was really a point indicator. Thereafter most switches were provided with indicators and the best policemen were chosen to work them. In 1839 Brunel designed « capstans » for working facing points and at the same time indicating their position.

Mixed gauges at Swindon in the 'eighties.

The earliest mention of a fixed signal on the G. W. R. proper was in 1840, when the line was opened to Reading. It was apparently a ball signal which, at the top of the post, indicated « clear », and when lowered meant « stop ». Brunel's disc and cross-bar signals, for many years standard on the Great Western, were introduced late in 1840. The signal consisted of a tall round mast with a large disc at the top to show « all right » and a cross bar immediately below and at right angles to the disc showed « danger », both generally perforated to lessen wind resistance. The signal was reversed by means of a lever at the foot of the mast. These signals gave a positive « all right » instead of the absence of a danger signal being taken to indicate « all right » as on other lines at the time.

For a « caution » indication, flag signals were first used but, owing to their rapid destruction by the wind, they were soon replaced by an arrow shaped wooden board on a revolving post, known

as a fantail signal. These were fixed on the left of the line to which they applied, and were red on one side and green on the other. They were introduced in 1842 and remained in use for a quarter of a century. The picture of a gauge conversion staff train of 1872 shows examples of both stop and caution signals, as well as of a junction signal. The disc and cross-boards, with their subsidiary fantail caution boards, were the universal signals until those between Paddington and Kensal Green were replaced by semaphores on April 1, 1865. By November, 1869, semaphores had been substituted for the old type of signal practically throughout the line. The semaphore at horizontal indicated « danger », and the « all right » indication was given by the disappearance of the semaphore vertically into a slot in the signal post. « Caution » was indi-



Standard G.W.R. permanent way and track troughs.

cated by the half-way position; this was not a reliable indication and by 1873 was abandoned.

The designation of distant signals by means of a notch cut in the end of the arm was adopted in 1876, and semaphores with the arm outside the post began to appear about the same time. The present standard form of signal was evolved about 1887, and the Great Western is notable for the fact that to this day, unlike the other main line companies, it retains the dropping arm to the exclusion of the upper quadrant type of signal.

On the Great Western the first locking frame is believed to have been that installed in 1860 just outside Paddington, and the use of locking frames rapidly extended thereafter. In July, 1903, a new signal box was brought into use at Didcot North junction, with all its points and signals worked and controlled electrically. Electro-pneumatic power was first adopted for the junction of the Windsor branch at Slough in 1913. Track circuits were introduced in August, 1908. These modern developments have, of course, been widely extended since. In 1863, although most of the longer stretches of single line were already being worked on the block system, only a few sections of double line were so worked, all the remaining double lines being controlled on the time interval system. By Christmas, 1873, the block telegraph was in use throughout between London and Bristol.

Safety of travel on the G. W. R. has been much enhanced by the adoption of a system of automatic train control by means of which audible warning is given to the enginemen of the condition of distant signals, and in the event of one being passed at « caution » the train is stopped automatically before it reaches the next signal. There is a steel ramp, 40 ft. long and rising to 3 1/2 in. above rail level, midway in the four-foot opposite the distant signal, and connected to the signal lever electrically. When the signal is at « caution » the ramp is dead; the action of pulling the lever to give a « clear » indication of the distant signal completes an electric circuit and energises the ramp. On the locomotive is fitted an iron shoe, with a T-shaped end extending head downwards to within 2 1/2 in. of rail level. As the engine passes over the ramp the head of the T comes into contact with it and is lifted 1 in. If the signal is at « caution » the ramp is dead, and the action of lifting the shoe opens a valve on the vacuum-automatic brake apparatus and causes the brakes to be applied throughout the train, at the same time sounding a siren in the engine cab. If the signal is in the « clear » position, the ramp is energised and the electric current, passing through the shoe, prevents interference with the vacuum brake, but rings an electric bell in the engine cab. This type of signal was first introduced on the Henley branch in January, 1906, and on the Fairford branch in December of the same year. By September, 1931, the whole of the Great Western Railway main lines, totalling 2 130 miles had been equipped, as well, of course, as all the locomotives liable to work over these lines.

[624. (09 (.42)]

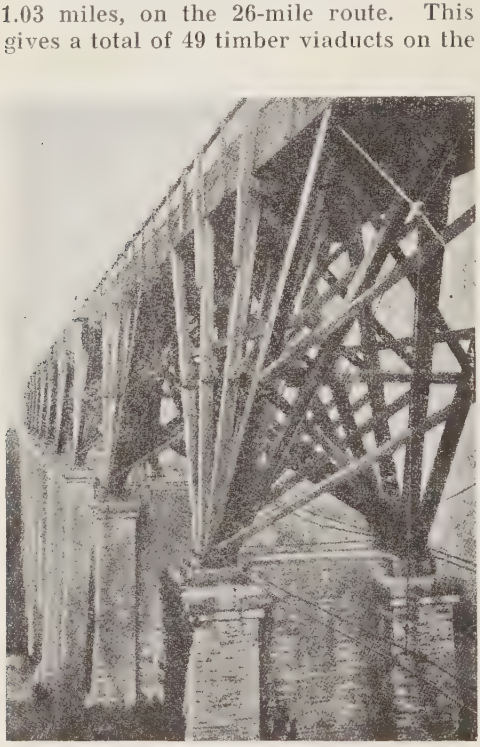
Brunel's timber viaducts.

(*The Railway Gazette*, Great Western Centenary number).

To dwellers in the West of England at least, among the best known examples of Brunel's work must have been his timber viaducts. Some men, faced with the task of building a railway across the undulating country of Devon and Cornwall, might have been remembered locally as despoilers of the landscape, but the first Chief Engineer of the Great Western Railway had a mastery of his material and a gift of design which served actually to enrich the scenery of the many valleys bridged by his slender and graceful spans. It must be a matter for regret that none of them has survived into the company's centenary year, yet it was by the narrow margin of six months that the last example — Collegewood viaduct on the Falmouth branch from Truro — failed to do so, and six months is a small proportion of a life of seventy-one years. Collegewood finished its career on July 21, 1934, with the passing of the 10.50 p. m. train from Falmouth to Truro. It began its service when the Cornwall Railway was extended to Falmouth on August 24, 1863.

The earliest timber viaducts in the West, however, were those on the South Devon Railway between Exeter and Plymouth, which was reached on May 5, 1848. There were seven viaducts on this section, of which five were timber and two, those at Rattery and Brent, of masonry. The line of the Cornwall Railway between Plymouth and Truro, opened on May 4, 1859, had 34 timber viaducts in a distance of 12 miles, aggregating about

4 miles in length; on the West Cornwall Railway, which provided a continuation to Penzance as from August 25, 1852, there were 10 timber viaducts, totalling 1.03 miles, on the 26-mile route. This gives a total of 49 timber viaducts on the



Walkham viaduct on the Launceston branch.

lines composing what is now the main route of the Great Western Railway from Paddington to Penzance.

It will be convenient to consider them in order from east to west, which brings us first to the five examples on the South Devon Railway. Their names and dimensions were as follow :

	Length.	*Height.*
Glaze	163 yards.	80 feet.
Bittaford . . .	117 —	61 —
Ivybridge . . .	252 —	114 —
Blackford . . .	293 —	107 —
Slade	273 —	100 —

They consisted of a pair of timber-trussed beams each supported by a single arch, the superstructure being carried on masonry piers. Between 1861 and 1863 wrought-iron girders were substituted for the timber superstructure.

The line of the erstwhile Cornwall Railway from Plymouth to Truro, traverses many cross valleys of depths too great to be economically filled by embankment, and it was necessary to build structures capable of carrying the lines across the valleys. Their names will be found hereafter :

1. Stonehouse Pool.
2. Keyham.
3. Weston Hill.
4. Coombe-by-Saltash.
5. Forder.
6. Wivelscombe.
7. Grove.
8. Nottar.
9. St. Germans.
10. Tresulgan.
11. Coldrenick.
12. Treviddo.
13. Cartuther.
14. Bolitho.
15. Liskeard.
16. Moorswater.
17. Westwood.
18. St. Pinnock.
19. Largin.
20. West Largin.
21. Draw-wood.
22. Derrycomle.
23. Clinnick.
24. Penadlake.
25. Milltown.
26. St. Austell.
27. Gover.
28. Coombe.
29. Fal.
30. Probus.
31. Tregarne.
32. Tregagle.
33. Truro.
34. Carvedras.
35. Penwithers.
36. Ringwell.
37. Carnon.
38. Perran.
39. Ponsanooth.
40. Pascoe.
41. Penryn.
42. Collegewood.

The longest structure on this section of railway was Truro viaduct, 1 290 ft., and St. Pinnock was the highest, 151 ft.; there were 16 others over 90 ft. high. Weston Mill and St. Germans were the largest and highest respectively of those which were built across the tidal creeks.

Mud deposits up to a depth of 70 ft. existed in the creeks, and the bridges across them depended on timber trusses to carry the decking and the railway, and these trusses were for the most part supported on timber piles, which formed the piers. The usual span for this type of viaduct was 40 ft., the height ranging from 10 ft. to 100 ft. Brunel so designed the timber viaducts that any piece of timber could be renewed under the usual

occupations afforded by the Traffic Department, and it was owing to this foresight that few difficulties were experienced in carrying out the repair work.

Where good foundations were to be had, however, the viaducts had masonry piers built from 60 ft. apart (centres) and carried up to cill level, about 35 ft. below that of the rails. From the tops of these piers three sets of struts radiated fanwise, four struts in each set, making 12 on each pier. The struts were kept in place by horizontal walings and diagonal braces of timber, and on the top of the struts were the main carrying beams in three runs for a single line of railway. The beams were double and the top and bottom beams united by raking bolts, joggles and keys. The top

An early engraving showing general view of the Slade viaduct.

width of the viaducts varied from 15 to 16 1/2 ft., according to the construction of the parapets. A good example of this type of construction existed in the old Ponsanooth viaduct on the Truro-Falmouth branch.

Stonehouse Pool viaduct on the Cornwall Railway was not replaced until 1908, so that it was the last of Brunel's timber structures to remain on the Great Western Paddington-Penzance main line. It began its useful life eight years before the down Flying Dutchman started running through to Penzance in the summer of 1871, and saw the first four years of what is now the Cornish Riviera Limited. This was the only one of the timber viaducts to be built for carrying a double track.

The ten viaducts of the West Cornwall Railway were as follow :

43. Penwithers.
44. Chacewater.
45. Blackwater.
46. Redruth.
47. Penponds.
48. Angarrack.
49. Guildford.
50. Hayle.
51. St. Erth.
52. Penzance.

The longest viaduct on this section was at Penzance, 1 055 ft., and the highest at Angarrack, 103 ft.; Penponds viaduct outlived the others as a timber structure by surviving until 1899. The viaduct at Penzance was replaced in 1871 and substituted with a stone embankment in 1921.

Collegewood viaduct, the last to remain of Brunel's famous timber structures in the West of England.

Forder viaduct.

Ponsanooth viaduct.

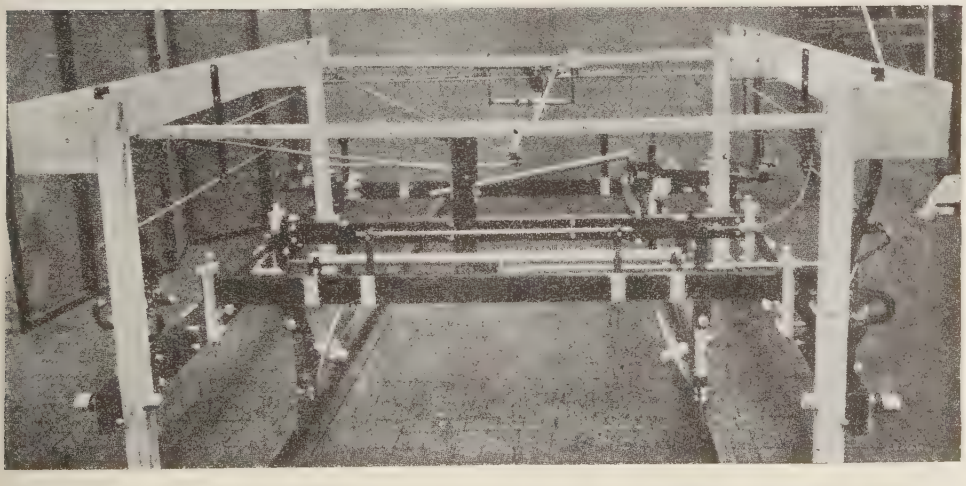
The conformation of the ground in Devon and Cornwall necessitated the construction of 67 viaducts, including those on the Launceston and Falmouth branches — 14 in Devonshire and 53 in Cornwall. All but two — those at Rattery and Brent — were of timber. Forty of them varied between 300 and 900 ft. in length; four exceeded 1 000 ft. in length, namely Truro, Walkham, Penzance and Nottar; the remainder were less than 100 ft. in length.

The cause of their disappearance was in part the difficulty of obtaining suitable yellow pine timber for upkeep at reasonable prices, a factor which began to be felt 25 years ago. Mainly owing to the high cost of maintenance, the principle of gradual replacement by embankment or masonry structure of the timber viaducts was adopted, with the underlying object of permitting the passage of heavier engines and consequent increased loads. The passenger's benefit will be considered by some as the countryside's loss, for after so long a life Brunel's timber viaducts had acquired a sense of harmony with their surroundings which admirers of the engineer's work may be slow to acknowledge in their successors.

[625.172 (.494)]

Dynamometer car track inspection equipment, Swiss Federal Railways.

(The Railway Gazette.)



Demonstration equipment to show working of Amsler apparatus.

Although an improvement upon earlier manual track inspection, the push trolley gauge and cant recorder was still a slow and unsatisfactory form of permanent way testing apparatus, as its records took no account of any appreciable load on the rails. In 1925 this was followed by the Hallade inspection car, and more recently by the Sperry gyroscopic track testing car. These were all special units devot-

ed to the recording of irregularities in the permanent way, but in 1930 the Great Indian Peninsula Railway ordered a dynamometer car from the Metropolitan-Cammel Carriage, Wagon & Finance Co. Ltd. that embodied certain track inspecting features of Amsler's design and was described in *The Railway Engineer* of November of that year. Meanwhile the Swiss Federal Railways had decided to add to their dynamometer car a track inspection equipment still more complete than that installed in the G. I. P. R. car, and entrusted Alfred J. Amsler & Co. of Schaffhouse with its supply. This equipment may be described as follows : the sketch diagram, figure 1, shows the layout of the apparatus, and figure 2 the exterior equipment of the car. In figure 3 may be seen the

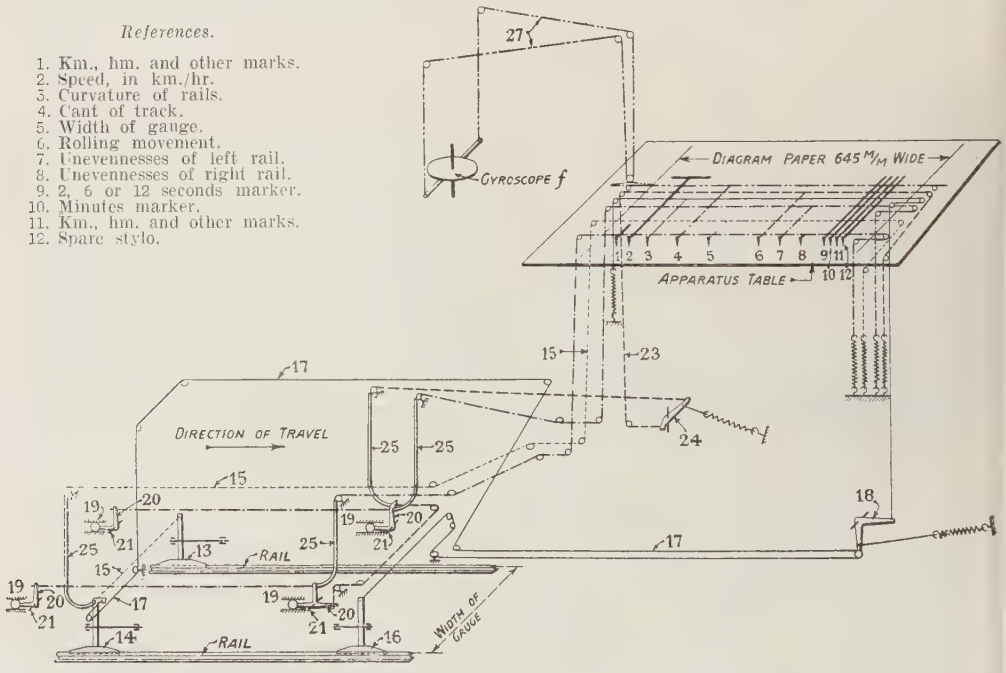


Fig. 1. — Sketch diagram showing the complete layout of the car equipment.

paper band on which the following records are plotted, while the train is travelling at about 30 m.p.h. :

Pen and
Record number :

1. Mileposts and other identification marks, such as stations, bridges, tunnels, etc.
2. Speed in km. p. h.
3. Curvature of track.
4. Super-elevation on curves, drawn to a scale of 1 : 5.
5. Gauge, shown to actual scale.
6. Rolling motion of car body, shown to a scale of 1 : 2, including relative transverse motion between wheels and body, due to irregular spring deflection, as for instance, on curves.
7. Irregularities in level of left-hand rail.
8. Ditto of right-hand rail.
9. Two-, six-, and twelve-second marks.
10. Minute marks.
11. Mileage and other marks as in 1.
12. Spare marker.

The pen carriers plotting records 2, 9, 10, 11 and 12 are operated by lengthening and bringing to the ordinates of the track inspection records the corresponding markers of the existing dynamometer table. Marker 1 is electrically coupled to marker 11, and facilitates the interpretation of the diagram.

The channel iron *b* in figure 2, which is suspended from the axleboxes of the bogie and is therefore unsprung, carries the various instruments for track testing. Exact gauge is measured by two shoes 13 (in figure 1) and 14, each about 2 ft. 2 in. in length, which are pressed against the inner rail faces by springs, the exact point of measurement being 0.6 in. below the rail table. Variations in gauge are continuously transmitted to recorder 5 by the cable 15. Similarly curvature is recorded by shoes 14 and 16 in contact with the right-hand rail, the resulting graph being proportional to the angle between the rail curve and the longitudinal centre

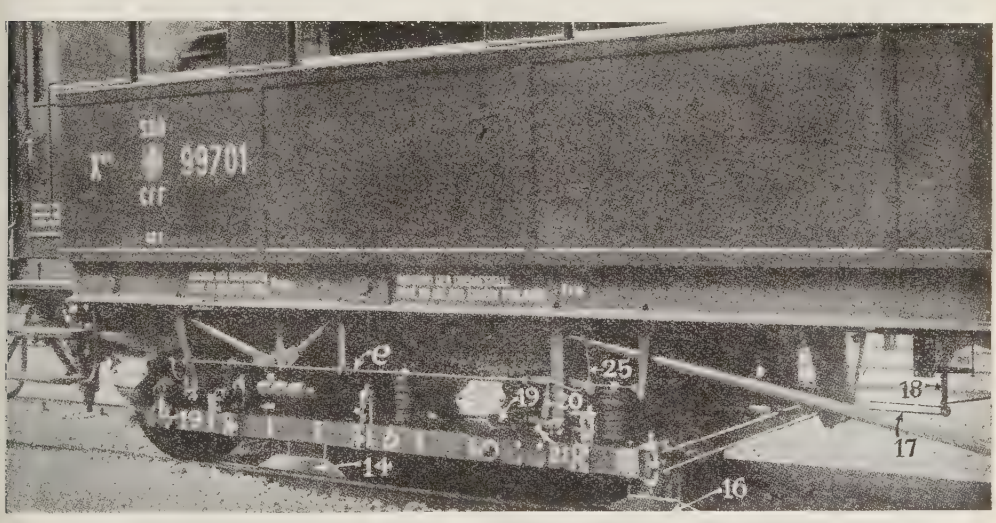


Fig. 2. — Exterior equipment as installed on the bogie and underframe of the car: the figures relate to features in the text.

line of the car midway between the two right-hand shoes. Actually a differential system of cables 17, transmits the difference between the distances of the shoes from the car centre line through bell crank 18 to style 3 on the recording table.

Irregularities in the right and left rail levels are registered by bell cranks 20, which pivot about pins 21 carried on brackets fixed to the car underframe. The rollers at the extremities of the crank arms move in double guides 19, fixed to the channel *b* (fig. 2) and perpendicular to the radius aligned to the bogie centre so as to make the rotation of the bogie ineffectual. The difference of vertical motion of the wheel centres relative to the car body, and therefore the irregularity of the rail level under the one wheel relative to the regular rail level under the other wheel is thus transmitted to pens 7 and 8 on the table, one for each rail. Rolling motion of the car body relative to the axles is taken up by the front pair of levers 20 and the difference is transmitted by a Bowden wire to pen 6 through cable 23. The dia-

gram is normally drawn to a scale of 1 : 2, but this can be varied by adjustment of lever 24.

In order to eliminate vertical vibration in the cables which are 2 mm, thick, they are led in tubes *e* (fig. 2), and the transfer from the bogie to the underframe is by means of Bowden wires 25. Carefully adjusted springs also minimise vibration and therefore inaccuracy in measurement and plotting, and the inertia of the lever part of the measuring system is reduced to a minimum by the use of light metal deflection rollers on ball bearings. Any deflection or tendency to distortion of the channel

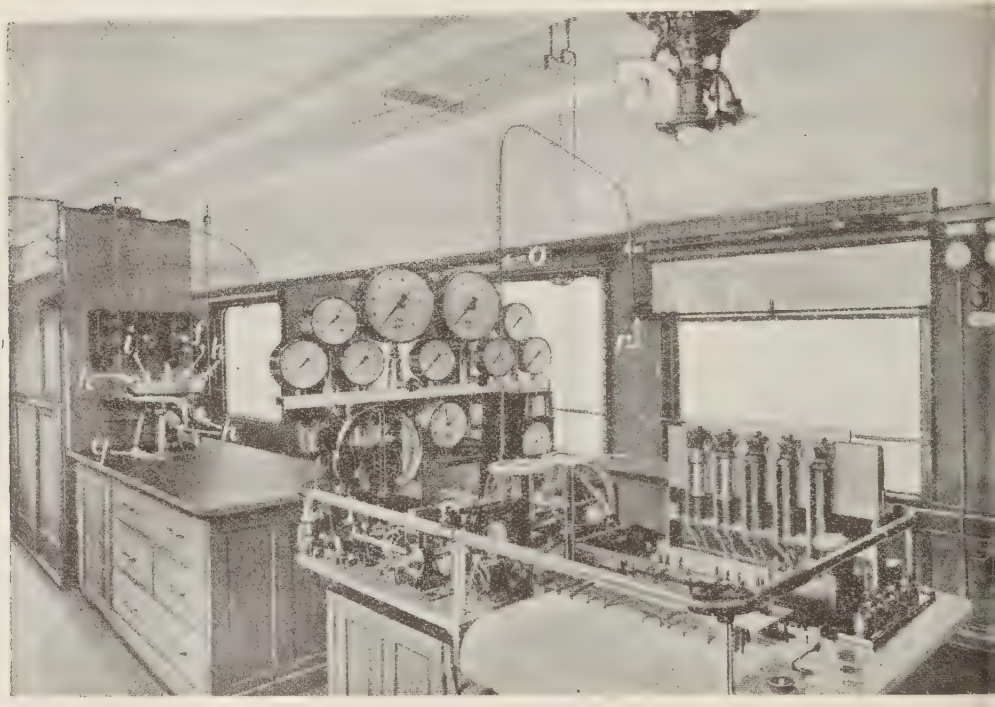


Fig. 3. — Interior equipment showing the paper band complete which 12 pens in the foreground : behind is the gyroscope and its accessories.

iron measuring base on curves is prevented by the use of ball-and-socket instead of rigid joints between it and the transverse members of this recording base frame on the bogie axleboxes. The channel members are also padded with wood to avoid vibration. When the apparatus is not in use the shoes 13, 14 and 16 (figs. 1 and 2) are turned upwards and hung from the underframe on hooks; the cables are disconnected and their ends hooked into special holders.

For recording the superelevation on curves, the gyroscope *f* shown in figure 3 is used with vertical axis, suspended very nearly at its centre of gravity. The base *g* is rigidly fixed to the carriage body, in this case through the medium of a tool cupboard. The gyroscopic disc, enclosed in a light

metal casing *i*, is driven by a direct-coupled d.c. motor of about 870 w. capacity with shunt excitation, and rotates at about 7 000 r.p.m. Current is supplied by a series of ordinary carriage lighting batteries. The free self-oscillation of the gyroscope is of long period. For eliminating the interference caused by the movement of the carriage, four electro-magnetic stabilisators *h* are arranged at angles of 90°. The control of the gyroscope motor is effected by means of a switchboard, where a voltmeter and ammeter are also arranged to check up the current supplied to the motor. The variations in the inclination of the carriage body are composed of (*a*) cant of the track (difference in level of the rails in relation to the horizon) and (*b*) rolling movement of the carriage body. The apparent motion of the gyroscope relative to the car body, *i.e.*, the sum of the cant of the track, the rolling movement, and free oscillations of the gyroscope, are transmitted to the recording pen 3 on the measuring table by means of the two silk threads 27 running along the carriage roof.

As there was no room left on the table of the main apparatus of this dynamometer car for the gyroscope, it had to be set up on the tool cupboard at a distance. This necessitates the correction of the gyroscope graph for rolling motion, and for this purpose a special pantograph is used. The correction is made purely mechanically, by circumscribing both graphs at the same time, the rolling movement being automatically transferred from the scale 1 : 2 to the scale 1 : 5 (corresponding to the two different diagram scales) and deducted from the gyroscope diagram placed above; the true cant of the rails is directly drawn in coloured ink. This unfortunately entails loss of time, and in an inspection car designed exclusively for track recording, the gyroscope would, of course, be accommodated on the apparatus table itself, and the deduction of the rolling motion from the gyroscope diagram would be made automatically. The gyroscope record would then represent the true cant of the track, and the recording of the rolling movement could be dispensed with or not, as desired. When not in use the gyroscope rotor can be fixed and supported by means of a screw in the table.

The diagram paper *a* (fig. 3) moves in the direction of the arrow at a speed of 200 mm. for each km. run, a speed which makes it possible to recognise the records made at individual rail joints, as the length of an 18 m. (59 ft.) rail is shown on the diagram by a measurement of 3.6 mm.

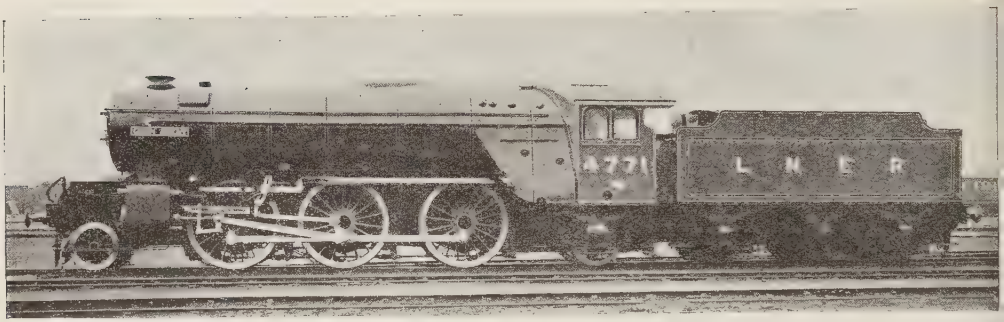
By means of a special arrangement on the electric contact of the kilometre marker on the measuring table at the start, the diagram is set to the particular kilometre on the track at the start of an inspection trip. An electric horn signal draws the attention of the operator stationed at the measuring table when passing each kilometre stone. By pressing on the button 28 (fig. 3), the stylos of the markers 1 and 11 are deflected, to mark on the diagram bridges, tunnels, crossings, etc., as they are passed by the inspection car, in order to localise readings. A window at the rear end of the car facilitates the observation of the track. The measuring and recording apparatus described above permit the inspection of close on 200 km. of track a day.

Another attachment, which was added to the dynamometer car at the same time, automatically shows the position of the car on the track. The plan of the track to be investigated is pinned to the board *n* (fig. 3) fixed in front of the recording table. The flexible shaft *o* driven from the measuring table actuates the pointer *p* which slides on the horizontal spindle *q*. A reversing gear *r* allows the pointer *p* to be moved forwards or backwards, *i. e.*, from left to right or *vice versa*.

RECENT DEVELOPMENTS.

IN RAILWAY PRACTICE.

2-6-2 three-cylinder engine « Green Arrow », London and North Eastern Railway.



The first of a series of 2-6-2 type three-cylinder tender locomotives has recently been completed at the Doncaster Works of the London and North Eastern Railway, to the designs of Sir Nigel Gresley, the Chief Mechanical Engineer of the Company, to whom we are indebted for the description, photograph, and diagram reproduced hereafter.

It is numbered 4771, and has been named « Green Arrow ». It is intended for express goods and passenger traffic.

The boiler follows the design of the A. 3 type *Pacific* engines. It has a grate area of 41.25 sq. feet; a firebox volume of 252 cu. feet, and a total evaporative heating surface of 2 431 sq. feet.

Two 3 1/2″ Ross Pop safety valves are fitted, with a working pressure of 220 lb. per sq. inch.

The firebars are of special design giving a ratio of air space to total grate area of 56 %.

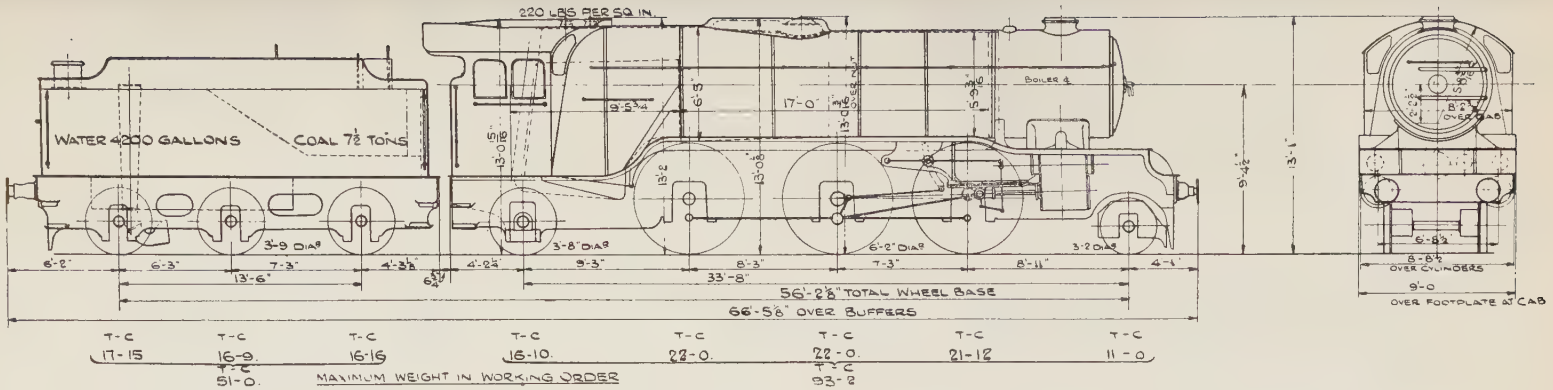
The boiler barrel has a maximum diameter of 6′ 5″, and is 17′ 0″ between the tube plates. It is provided with a steam collector through which all steam entering the regulator must pass. The entrance to the steam collector is through a series of circumferential slots cut in the top of the barrel plate, an arrangement which has proved successful against priming. In order to avoid wire-drawing through the slots their total area has been made equal to twice the area through the regulator.

The double beat type regulator together with the internal steam pipe are of particularly ample proportions for an engine of this size, having steam area of 38 sq. inches. Three 5″ internal diameter smokebox steam pipes are provided.

The 43-element « Robinson » superheater header is a steel casting, and is fitted with an anti-vacuum valve of the L. N. E. R. type. The elements are 1 1/2″ external diameter, and have short loops.

The cylinders are 18 1/2″ diameter, and 26″ stroke with 9″ diameter piston valves.

The three cylinders, steam chests, the smokebox saddle and all steam and exhaust passages are cast as one unit. The



Leading dimensions and ratios.

Grate :

Length on slope	5' 10 15/16"
Width	6' 11 3/4"
Grate area	41.25 sq. ft.

Firebox :

Height of crown above foundation ring — Back	6' 8 13/16"
Height of crown above foundation ring — Front	6' 0 5/16"
Interior length at top	7' 11 3/4"
» width at boiler centre	5' 4 1/2"
Tickness of copper plate — Sides & back	9/16"
Tickness of copper plate — Tubeplate	9/16" & 1 1/4"

Boiler :

Outside length of firebox, overall	9' 5 3/4"
Outside length of firebox, at bottom	6' 8"
Outside width of firebox, at bottom	7' 9"
Maximum diam. of barrel	6' 5"
Tickness of barrel plates	23 32" & 25/32"
» » wrapper «	9/16"

Tubes, small :

Material	Steel
Number	121
Diameter outside	2 1/4"
Thickness	10 I. W. G.

Tubes, superheater flues :

Number	43
Diameter outside	5 1/4"
Thickness	5/32"
Length between tube plates	17' 0"

Heating surface :

Firebox	215 sq. ft.
Tubes	1 211.57 » »
Flues	1 004.5 » »
Total evaporative	2 331 » »

Superheater :

Number of elements	43
Diameter inside	1.244"
Heating surface	679.67 sq. ft.
Total H. S.	3 110.74 sq. ft.
Two Ross pop safety valves	3 1/2" diam.
Working pressure	220 lb./sq. in.

Axles :

	Diam.	Length
Journals, pony	6 1/2"	× 9"
» coupled	9 1 2"	× 11"
» trailing	6"	× 11"

Crank pins :

Outside	5 1 2" × 6"
Inside	8 1 4" × 6"

Coupling pins :

Leading	4 3 4" × 3 1/2"
Driving	6" × 4 1 4"
Trailing	4" × 4 1/2"

Springs : Pony, helical, 10 3/16" long free, 5 1/2" outside diam., Timmis section. Coupled wheels, laminated, 5" wide, 1/2" thick, 16 plates, 4' 0" centres. Trailing wheels, laminated, 5" wide, 5/8" thick, 11 plates, 4' 6" centres.

Brakes : Vacuum.

Cylinders :

Number	3
Diameter	18 1/2"
Stroke	26"

Motion :

Type, outside	Walschaerts
» inside	Gresley
» valves	Piston
Diameter of valves	9"
Maximum valve travel	5 5/8"
Steam lap	1 5/8" outs. cyl.
Exhaust lap	Nil
Cut-off in full gear	65 %
Tractive effort at 85 % boiler pressure	33 730 lb.
Total adhesive weight	146 944 lb.
Adhesive weight / Tractive effort	4.3

outside steam pipes are also integral with the main casting. Each cylinder is fitted with spring loaded relief valves of large diameter in addition to the usual cylinder drain valves. The latter are operated from the footplate by « Bowdenex » cable.

The piston heads and rods are combined in one forging of « C » Class steel. Each head is fitted with two rings 5/16″ wide. Cast iron packing is used for the piston glands.

All three cylinders drive the second coupled axle. The crank axle taking the drive from the centre cylinder is of five-part built-up construction.

The coupled wheels are each 6′ 2″ diameter.

The whole of the revolving, and 40 % of the reciprocating, masses are balanced. The revolving at the centre crank is balanced by means of extensions to the crank webs, while the remainder is balanced in crescents cast in the wheel centres.

The coupled journals are of ample proportions, being 9 1/2″ diameter × 11″ long. They are lubricated by a 6-feed Wakefield mechanical lubricator carried on the left hand footplate. The gearing operating the lubricator as well as a similar lubricator for the cylinders is fitted with ball bearings throughout.

Armstrong oiler pads are fitted to the underside of each journal.

The connecting and coupling rods are of nickel-chrome steel and are lubricated by means of pin trimmings. Felt pads are fitted at the top and bottom of each bearing.

The valve gear is of the type fitted to over 470 locomotives on the London & North Eastern Railway; the valves for the outside cylinders are operated by Walschaerts gear and the inside valve is driven through 2 to 1 and equal levers from the outside valve spindles.

The maximum cut-off is 65 % in which position the valve travel is 5 5/8″.

Ball- and roller bearings are fitted to the valve gear throughout.

Vacuum brake is fitted to both engine and tender. There are two 24″ diameter brake cylinders on the engine and two 21″ diameter on the tender giving a brake power at the blocks equal to 67 % of the weight on the braked wheels. A Davies & Metcalfe ejector is fitted.

The leading pony truck is the double swing link pattern giving a translation of 5 1/2″ either side of the centre position. All the swing link pins and slides are grease-lubricated.

The trailing carrier wheels are fitted with « Cartazzi » axleboxes with a maximum translation of 2 1/2″ either side of the central position.

The cab front is extended into a wedge form. The large front windows give a particularly good look-out for the enginemen; these windows are fitted with Triplex safety glass. Side windows and side look-out screens are also provided.

The boiler is fed by a Davies & Metcalfe type « H » exhaust steam injector on the right hand side, and by a Gresham & Craven No. 11 live steam under footplate pattern injector on the left hand side.

The boiler barrel and firebox are insulated with « Alfol » foil made up in the form of mattresses : the cylinders with asbestos.

The engine is fitted with hand-operated sand gear to the leading wheels and steam sanding equipment to the driving wheels.

The sandboxes and ashpan are of entirely welded construction.

The 6-wheeled tender carries 7 1/2 tons of coal and 4 200 gallons of water.

Screw-operated water pick-up equipment is provided.

The weight of the engine and tender in working order is 144 tons 2 cwts.

MISCELLANEOUS INFORMATION.

[661. 132.6 (.45)]

1. — 4-6-4 h 2, class 61, streamlined tank locomotive built by Henschel & Sohn, Cassel, for the Deutsche Reichsbahn.

(From *Die Lokomotive*, Vienna).

The Reichsbahn has in service two streamlined 4-6-4 locomotives with separate tenwheeled tenders, the second of which, on its recent trial run, reached a speed of 192 km. (119.3 miles) an hour, or 440 r.p.m., whereas the regulations allowed a speed of 156 km. (96.9 miles) an hour at 360 r.p.m., corresponding to a working speed of 150 km. (93 miles). It should be remembered that twenty years ago, in 1915, an Austrian 4-8-0 class 570 Südbahn locomotive with wheels of only 1.74 m. (5 ft. 8 1/2 in.) diameter reached a speed of nearly 130 km. (80.8 miles) an hour, its 400 r.p.m. being only 10 % less, in spite of its being a simple-expansion engine and more particularly an eight-coupled one.

In the interest of steam locomotive progress, the Reichsbahn must be congratulated on having made a trial with a simple expansion engine. By using a markedly longer stroke, 750 mm. (29 1/2 in.) instead of 660 mm. (26 in.) almost the same cylinder diameter was sufficient, 460 mm. (16 1/8 in.) instead of 450 mm. (17 11/16 in.).

As the piston pressure is only 33 t. (32.5 Engl. tons) against the 41 t. (40.35 Engl. tons) of the 4-8-0 Austrian locomotive, there is no doubt the engine will reach at least the same speed. The designed piston speed is, of course, unusually high, but will not cause any difficulty with the present design of packings and mechanical lubricators used. The use of a tank engine is a further guarantee of very high speed and at the same time of good riding.

The excellent results obtained with the famous 4-6-4, class T 18, and 4-6-2, class 629, locomotives will be remembered. These, engines, in spite of having 1.650 m. and 1.629 m. (5 ft. 5 in. and 5 ft. 4 1/8 in.) driving wheels, can be considered as real express engines capable of covering moderate distances of some 200 km. (124 miles) at a working speed of 90 km. (56 miles) an hour. Their grate area is 2.70 m² (29 sq. ft.) and boiler pressure 20 kgr. (284 lb. per sq. in.) and their estimated horse-power is 1 500, so that they can run 150 to 200 km. (93 to 124 miles) without taking water.

Unlike the tender engine, the tank engine is to be used to haul a special rake of 4 bogie carriages of light construction on the lines of the high-speed railcar trailers. The tare is 30 or 32 t. (29.5 or 31.5 Engl. tons) per carriage and the corresponding train weight 260 to 268 t. (256 to 264 Engl. tons) instead of 410 t. (403.5 Engl. tons) hauled by the 05 class. As the two locomotives have the same adhesive weight, the tank engine with a train of half the weight has a great advantage over the other, as it can accelerate much more rapidly.

The locomotive and coaches are fitted with the Scharfenberg automatic coupling which connects the brake and other pipes at the same time. The boiler is set high enough to allow the firebox to project over the bar frames whilst having deep enough water legs. The grate has thus been made wider and the cross section of the firebox improved, the 80 mm. (3 5/32 in.) thick bar frames being dropped down forwards between the trailing coupled wheels, as usual with 4-6-0 engines.

In order to save still more weight, all the connections between the frame and the cylinders as well as the slide-bar and motion

Fig. 1. - Streamlined 4-6-4 class 61 express tank locomotive, built by Henschel & Sohn, Cassel, for the Deutsche Reichsbahn.

Cylinder, diameter	460 mm.	*(16 1/8 in.)*
» stroke	750 mm.	*(29 1/2 in.)*
Driving wheel diameter	2 300 mm.	*(7 ft. 6 9/16 in.)*
Bogie wheelbase	2 350 mm.	*(7 ft. 8 1/2 in.)*
Carrying wheel diameter	1 100 mm.	*(3 ft. 7 5/16 in.)*
Rigid wheelbase	5 100 mm.	*(16 ft. 8 25/32 in.)*
Total wheelbase	14 350 mm.	*(47 ft. 1 in.)*
Pressure	20 kgr./cm²	*(284 lb. per. sq. in.)*
Length of tubes	5 000 mm.	*(16 ft. 5 in.)*
Grate area	2.75 m²	*(29.5 sq. ft.)*
Firebox heating surface : fireside	14.2 m²	*(153 sq. ft.)*
Tube heating surface	137.7 m²	*(1 476 sq. ft.)*
Evaporative heating surface	151.9 m²	*(1 629 sq. ft.)*
Superheating surface	69.2 m²	*(745 sq. ft.)*
Feed water heating surface	8.6 m²	*(92.6 sq. ft.)*
Water carried	17 m³	*(3 740 Br. gall.)*
Coal carried	5 t.	*(4.9 Engl. tons)*
Weight, empty	99.7 t.	*(98.1 Engl. tons)*
» in running order	128.3 t.	*(126.3 Engl. tons)*
» adhesive	55.6 t.	*(54.7 Engl. tons)*
Water in the boiler	6 m³	*(211.8 cu. ft.)*
Boiler steam space	2.7 m³	*(95.3 cu. ft.)*
Evaporative surface	9.86 m²	*106.1 sq. ft.)*
Maximum speed	175 km./h.	*(108.7 m.p.h.)*
Smallest radius of curve	180 m.	*(9 chains)*

brackets have been welded. The Walschaerts valve gear gives early cut-offs, but has large passages.

In all high-speed stock the braking is of first importance. The Hildebrand-Knorr high-speed brake used on the locomotive we are describing operates two blocks on all wheels, which are braked to 180 % of the static load, with the exception of whichever bogie is leading. The leading wheels of this bogie are braked to 50 % and the trailing 80 %, the change over from one to the other bogie being done by a change-over cock.

Included in the fittings are the following):

two 10-kw. turbo-generators for lighting the engine and train, for the inductive train control, for ventilation, and heating the train by hot air, as well as for operating the automatic foot-step lifting gears operated simultaneously from the two driving compartments, which are duplicates of each other.

The water tanks are in five sections, two of the usual shape along the boiler barrel, two between the frames, and the fifth behind the coal bunker, all interconnected by levelling pipes.

The engine casing is streamlined and encloses the whole engine, the necessary doors and shutters being provided to give access for service purposes. The engine and carriages are painted in the same colours as the Rheingold, bluish red up to the windows, ivory above except for the roof which is painted black on account of the smoke.

[621. 335 (.44) & 625. 215 (.44)]

2. — Electric motor bogie.

(Les Chemins de fer et les Tramways.)

The O. C. E. M. (Office Central d'Etudes de Matériel de Chemins de fer) (France) recently patented an electric motor bogie of a new type which is both lighter and simpler and has the minimum unsprung weight. In this design the motors form part of the bogie frame, and the sole bars are carried by the axle boxes through springs in such a way that the motors are entirely spring borne.

The following is the arrangement :

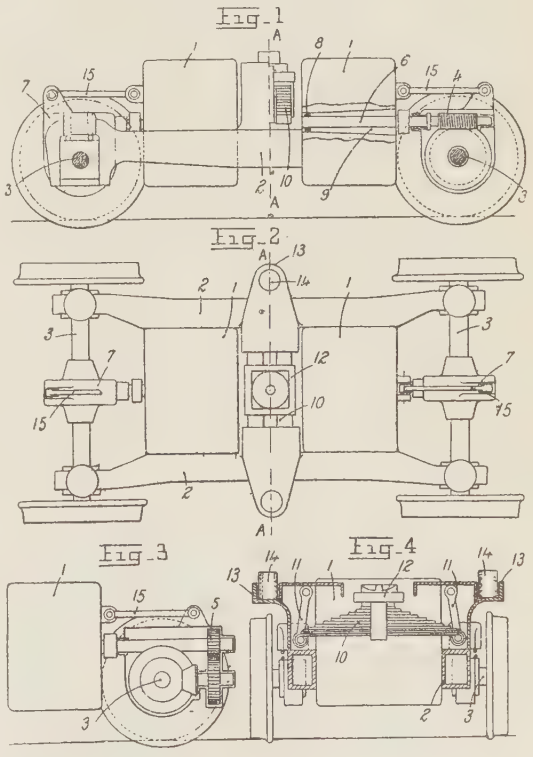
1. *When two traction motors are used.*

The centre lines of the two traction motors lie in the vertical plane through the longitudinal axis of the bogie; the casings of these motors either cross-brace the sole bars or form part thereof.

The motion is transmitted from one of the motors to the axle either by a worm gear 4 (figs. 1 and 2) or by toothed gears (fig. 3). In both cases these gears are driven by a cardan shaft, 6, articulated on the driving shaft of the gear box, 7, and at its other end, 8, at the end of the hollow-bored shaft nearest the bogie centre.

The bogie bolster with the springs, 10, the links, 11, and centre pin socket, 12, on which the body centre pin rests, is located between the two motors.

The supports, 13, of the spring bearings 14, carrying the body, are formed either by extensions from the motor casings or by brackets on the soles.



O. C. E. M. motor bogie.

Legend { 1. Motors. 2. Soles. 3. Axles

Articulated links, 15, between the motor and gear boxes take the thrust whilst allowing relative movement between the motors and axles.

2. *When one motor is used.*

In this case the traction motor is fitted at the centre of the bogie. The cardan shafts transmitting the driving torque to the gear boxes are articulated inside the hollow shaft of the motor at the centre of the bogie. Two designs of centre plate are used : either the centre pin socket is carried by the motor through a spring or it is carried on a bogie bolster carried in turn by two longitudinal springs carried by links from the soles.

3. *Alternative arrangement.*

In order that the weight of the gear boxes may not be directly carried by the axles, the gear boxes may be built into the end plates of the motors. In this case the drive is by quill; the cardan shafts are not required and the armature shafts are of the usual type.

The advantages of these arrangements are :

1. The place of the bogie frame is taken by the motor frame, which either forms the central part of the soles or the soles themselves; the motor casings can be bolted to the soles or be solid cast with arms replacing the soles. This reduces the weight of the bogie to the minimum.

2. Reduction to the minimum of the unsprung weight, which is only made up of the weight of the wheels, axles and axle boxes, and gear boxes (in the first two designs), whereas in the case of nose-suspended motors a considerable part of the weight is carried by the axle directly. When the gear boxes are built into the motor, the unsprung weight only includes the driving wheels and axles and axle boxes with part of the spring drive.

3. The mass of the motors being brought in towards middle of the bogie, the inertia force, when negociating curves, is appreciably reduced.

4. The large spring-borne weight (motors and soles) between the springs resting on the axle boxes and those carrying the body assist in damping out vibrations due to the track.

5. The torsional couple set up by the motors is easily neutralised by making the motors run in different directions; this couple is absorbed by the motor casings without any reaction on the carrying springs.

[**621. 132.7** (.436) & **621. 133.8** (.436)]

3. — Recording the work performed by shunting locomotives (the Chronhodograph),

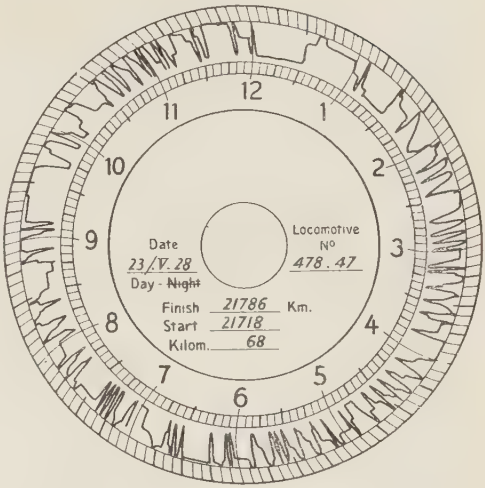
by C. CZEIGER, Engineer, Vienna.

(*The Railway Gazette.*)

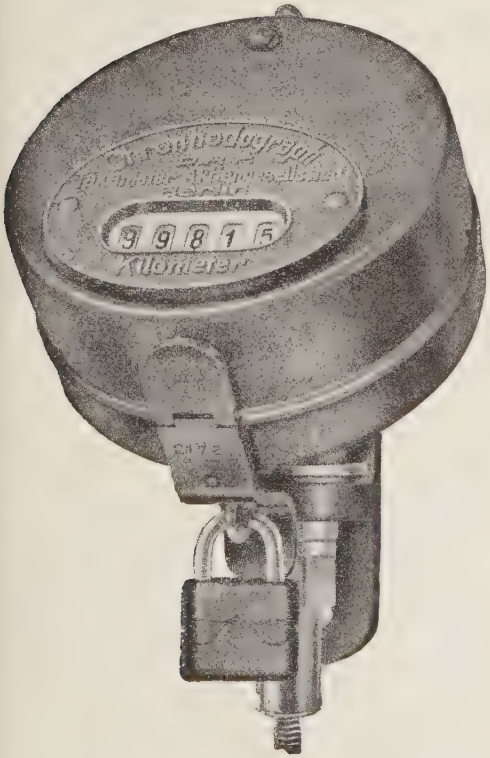
The work performed by shunting locomotives constitutes an item in railway expenditure which is not only considerable but also very difficult to check accurately by ordinary means. This work is normally accounted for in shunting hours, the returns being based merely on the estimates of the employees engaged. In terms of distance covered the work done is ascertained indirectly and by rule of thumb, varying between 3 and 8 miles per shunting hour, according to the practice and working conditions adopted by the different railway companies. The difference between these two limits shows up very clearly the doubtful value of this method of ascertaining the work done, and it is impossible to effect economies in the expenditure of labour and material accounts involved in shunting work because accurate figures on which to base the calculations are lacking.

With these considerations in mind, the Administration of the Austrian Federal Railways, after prolonged experimental investigation, adopted the instrument known as the

Chronhodograph, with a view to effecting more accurate control of shunting operations and ascertaining their cost, and the success achieved by the use of the instrument has exceeded all expectations. In spite of the fact that the work to be performed by a shunting engine depends on local requirements, the layout of the sidings, weather and visibility, and other factors, the records furnished by the new instrument provide sufficiently accurate and detailed information for the work to be carried out more economically. Whereas hitherto any increase in the total weight of the wagons shunted has been accompanied by an increase in the number of shunting hours, and therefore in the number of shunting engines



Typical stylo record from the Chronhodograph.



External view of time-distance indicator used on the Austrian Federal Railways.

required, and the total expenditure of labour and material, it has, since the introduction of the new checking method in 1926, been found possible to reduce the total number of shunting hours in spite of increasing gross ton-mileage, and thereby to achieve a very considerable saving in the number of shunting engines and the expenditure attendant thereupon. In one test period the work done was 400 million gross ton-miles higher than in the preceding period, whilst the shunting hours were reduced by 5 780, and it has been found possible since to improve very considerably on this result.

As its name indicates, the Chronhodograph is a time-distance indicator. Upon circular discs rotated by clockwork, a stylo records continuously all periods of movement as jagged lines, and all standstill periods as arcs. These check discs were originally designed for a twenty-four hours record, but experience showed that twelve-hour discs were preferable on account of their greater clarity. Each engine driver has his own disc for the time he is on duty, receiving it at the commencement of a shift and giving it up at the end of the shift as proof of the work done.

As can be seen from the illustration, the instrument at the same time registers the total

number of miles covered, this figure being entered on a check disc. In this manner the mileage per shift is also recorded, while the total amount of work done by the engine can always be read off at the instrument. The proper times for overhaul are deduced from the total mileage covered by the engine.

The instrument is so designed that any tampering, wrong treatment, or mechanical faults are at once revealed. The only manipulation required, apart from the insertion of the discs, is the winding up of the clockwork every twenty-four hours. The instrument is fixed on one side of the cab in such a manner that the discs can be easily inserted; it need not be watched during working, and therefore need not be placed so that it can be seen.

The drive for the recording and counting mechanism takes its motion from one of the axles, and it is immaterial whether the movement of the engine be forward or backward. Reverse gearing in the instrument ensures that movement in either direction is recorded continuously, unless it is specially desired to record forward and backward movement separately. The circumference of the wheel from the axle of which the drive is taken must correspond with the driving gearwheel of the instrument, but the latter is readily changeable to suit the circumstances. If the locomotive is already equipped with a speed indicator, a branch from the same drive can be taken to the Chronhodograph. In view of the springing, flexible driving shafts were originally used in Austria, but had the disadvantage of being easily broken. It is therefore preferable to use rod transmission with bevel gears at the angles, mounted above the springs and resilienlty connected with the driving wheels to allow for action of the springs. Transmissions of this type, with slotted driving cranks, have proved satisfactory in every respect.

[621. 155.2]

4. — A lateral-motion roller-bearing journal box.

(Railway Age.)

With the application of roller bearings to locomotive driving axles the Franklin Railway Supply Company, New York, one of the first to provide controlled lateral motion for locomotive driving axles, became interested in developing a means of applying this principle to roller-bearing journal boxes.

On locomotives with plain crown-bearing journal boxes the control and cushioning of lateral motion has been largely confined to one or two axles for the primary purpose of keeping the rigid wheel base within practical limits on locomotives with long coupled wheel bases. In the case of the roller-bearing journal box, however, because of the absence of lateral motion within the bearing itself there is to be considered the added function of providing some cushioned lateral movement within the parts of the journal box to protect the axle bearing, frames and parts from shocks received through the track. To meet these conditions this company has developed a type of lateral-motion journal box which is adapted to either self aligning or radial type roller bearings and is applicable on either inside or outside journal bearings, the latter including those on trailer, tender and passenger-car trucks.

For both types of bearings the complete lateral motion journal box consists essentially of an inside box which houses the roller bearing and an outside box which fits into the pedestal of the locomotive or truck frame or is otherwise attached to the truck frame. The inside box conforms to the outside of the roller-bearing assembly and is essentially cylindrical in form. Within it are provided the necessary seals for retaining the roller-bearing lubricant. On the top of the inside box is doweled the spring seat or the spring-saddle seat, as the case may be. The outside box is open on the side next to the wheel hub and, in assembling, is slid onto the inner box in a direction parallel to the axis of

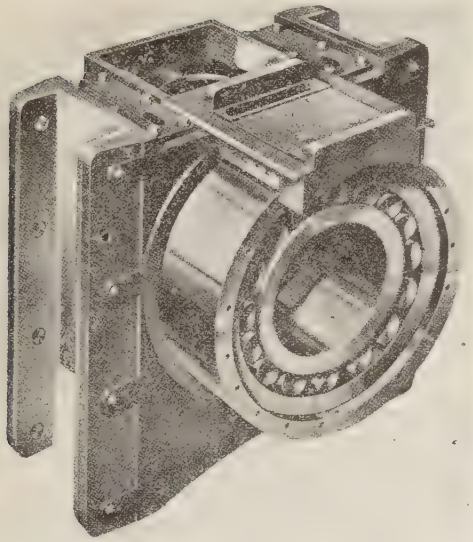


Fig. 1. — The inner box, with its inside cover removed, partially inserted in the outer box. When completely assembled all bearing surfaces are protected from dust.

the journal. The top of the outer box is also open for the doweled seat of the inner box on which the load is carried.

Lubrication of the sliding surfaces between the inner box and the driving box is provided from an oil pocket in the spring-saddle seat. Pockets in the top of the outer, or driving box, feed oil to the pedestal shoe and wedge faces. In the trailer box the oil pockets in the outer box supply lubricant to both surfaces. Alemite fittings in the inner box extend through free openings in the closed end of the outer box.

On the closed face of the outer box are a number of spring pockets which are parallel to the axle. Within each pocket is a coil spring which bears against a plunger projecting into the outer box toward the end surface of the inner box from which it is normally separated by a clearance of 1/64 inch. The lateral movement of the axle and the roller-bearing assembly with its inner box brings the latter into contact with the ends of the plungers in the outer box and builds up resistance against the movement by the compression of the springs. With the removal of the force causing the lateral movement of the axle, the springs acting on the plungers restore the inner box to its normal or central position within the outer box.

The illustrations show a driving box designed for SKF self-aligning bearings. With this type of bearing the movement required to accommodate the variable inclinations of the axle with respect to the frames takes place within the bearing itself, and full-length bearing surfaces between the flanges of the outer or driving box and the pedestal shoe and wedge surfaces can be maintained. The only friction load on the sliding surfaces between the inner and outer boxes is what may be imposed by braking reactions and, in the case of driving boxes, by the piston thrust. The main bearing load is carried directly on the inner box.

With a journal box of this kind it is possible to provide the amount of lateral cushioning force desirable on any particular axle, depending upon its location in the wheel base. By the number of cushioning springs built into the box and the initial load adjustment the amount of resistance can readily be developed to supplement the resistance of the leading

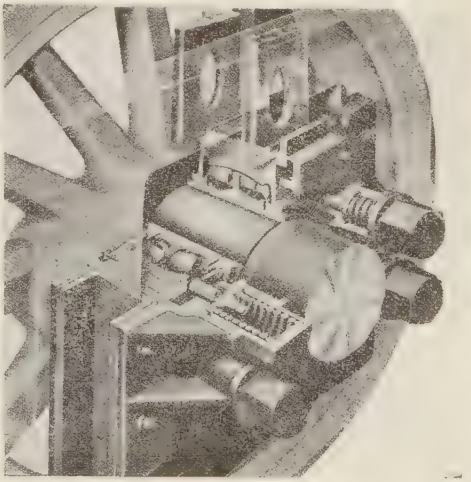


Fig. 2. — Lateral-motion roller bearing driving box cut away to show the relation between the parts.

truck or the trailing truck in any proportion to provide proper riding quality both at speeds and on curves. In the case of the drivers it can also be varied to meet the conditions of location and, hence, to provide the proper flexibility in order to negotiate curves and overcome the disadvantages of a too long rigid wheel base. The cushioning of the lateral not only tends to increase the life of the mechanism, including flanges, wheels, axles, bearings and boxes, but also reduces stresses on the rail and roadbed. By reducing flange clearance it would be possible with journal boxes of this type to replace what is in reality a free lateral movement between the flange and the rail with a cushioned and controlled lateral movement within the lateral-motion journal box.

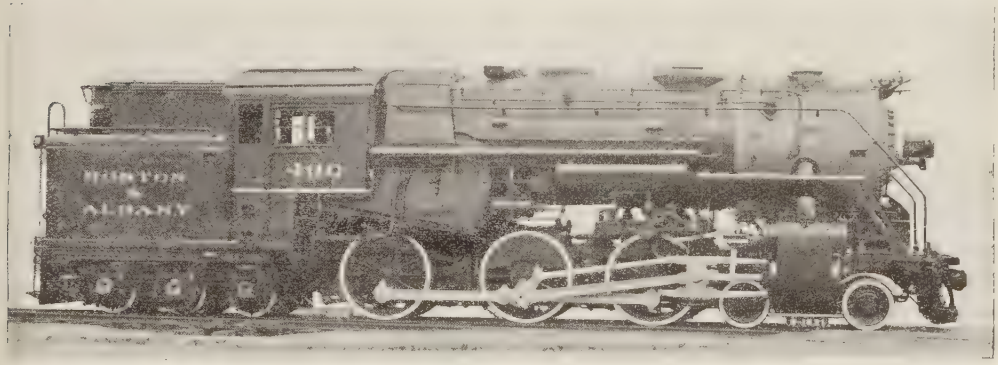
Journal boxes of this type have been in service on the front driving boxes and the front trailer boxes of two Delaware, Lackawanna & Western 4-8-4 type locomotives since December, 1934, one of these locomotives operating largely in passenger service and the other largely in freight service. In this installation the maximum lateral permitted within the driving boxes is 5/8 inch and within the trailer boxes, 1 inch. Observations made by the use of Bowden wires attached to one plunger each in a driving box and a trailer box indicate that in approaching a curve the lateral-motion boxes permit the axle to adjust itself smoothly and gradually and no side sway of the locomotive was evident either on tangent track or on curves due to a jerky lateral movement of the axles. When operating in the yard and in pusher service the lateral movement within the driving boxes varied up to a maximum of 1/4 to 3/8 inch, both in forward and backward motion. In backward motion the springs in the trailer box were compressed 5/8 inch under conditions of severe curvature, and in forward motion not more than 3/8 inch. Examination of the boxes, however, indicates that at times there have been lateral movements up to the maximum permitted by the design of the boxes. In road passenger service a reduction in the initial lateral force on the trailer boxes from 31.6 per cent to approximately 21 per cent of the wheel load was found to effect a smoother operation of the trailer. The initial force in the driving box has been maintained at 31.6 per cent of the wheel load.

[621. 132.6 (.492 + .73)]

5. — The heaviest tank locomotive in the world.

In the January 1935 number of this *Bulletin*, there appeared, on pages 121 et seq., an article by F. S. Dortmund, entitled as above and describing in particular a type of 4—8—4 tank locomotives in use since *1930* on the Netherlands Railways and weighing 124.4 long tons in working order.

Our attention is now being drawn to the fact that in *1928* a tank locomotive of the 4—6—6 type, weighing 157.1 long tons in working order, was supplied by the American Locomotive Company, New York, to the New York Central Lines (Boston and Albany). A side view and the leading dimensions and characteristics of this locomotive are given hereafter.



Class	466 TS 352
Road number	400
Track gauge	4′ 8 1/2″
Cylinders, diam.	23 1/2″
— stroke	26′ 0″
Driving wheel diameter	63′ 0″
Boiler, inside diam.	82 7/16″
— pressure	215 lb. per sq. in.
Firebox, length	102 1/8″
— width	85 3/4″
Grate area	60.8 sq. ft.
Tubes, number	234 and 48
— diameter	2″ and 5 3/8″
— length	13′ 6″

Evaporating surfaces :

Tubes	1 643 sq. ft.
Flues	905 sq. ft.
Firebox	189 sq. ft.
Arch tubes	24 sq. ft.
Total	2 761 sq. ft.
Superheating surface	788 sq. ft.
Fuel used	Soft coal.
Wheel base, driving	15′ 0″
— total	42′ 8″

Weight in working order :

Leading truck	62 000 lb.
Driving wheels	180 000 lb.
Trailing truck	110 000 lb.
Total engine	352 000 lb.
Maximum tractive power	41 600 lb.
Factor of adhesion	4.32
Tank, type	Rear
— water capacity	5 000 gall. (U.S.A.)
— fuel capacity	6 tons (short)

NEW BOOKS AND PUBLICATIONS.

[385. (09 (.493)]

LAMALLE (Ulysse), Assistant General Manager of the Belgian National Railways Company, Professor at the University of Louvain. — **Le Centenaire des Chemins de fer belges** (*The Belgian Railways Centenary*). — A pamphlet (11 3/4 × 8 1/4 inches) of 40 pages, with 61 figures. — Abstracted from the *Revue Universelle des Mines*, 12, Quai Paul Van Hoegaerden, Liége.

A hundred years ago, many countries, and Belgium in particular, were on the eve of a deep economic and social transformation, of which the railways were to be the cause.

From their encouraging beginning, they developed apace. By facilitating and improving communications, by carrying raw materials and manufactured goods long distances at low rates, they first of all met existing needs and then induced new ones. If they made possible and partly caused the expansion of large-scale industry, they also became a vital factor in its development.

Belgium was one the first countries to adopt the new form of locomotion. 1935 was the centenary of the opening of the Brussels-Malines line. It also saw the opening of the first main-line electric railway, now connecting the capital to the commercial metropolis which made the Brussels exhibition the more interesting.

The *Revue Universelle des Mines* invited Mr. Lamalle to celebrate the occasion by broadly outlining this long period during which the Belgian system, one of the densest systems in the world, has developed and improved to its present state.

The author obviously has not tried to write a history of the system which would have involved a work covering a much wider field. He has nonetheless called attention, on the long way covered, to the different interesting stages and pointed out the noteworthy inventions and applications adopted with their characteristic features, as well as the names of the initiators. Some of them, such as the Walschaerts valve gear, now in use throughout the world and the superheater with the elements in the flues, first tried in Belgium, are being increasingly used. Others disappeared owing to subsequent progress.

The author begins by a brief historical review which brings before us the birth of the railway. He shows how the railway, first introduced down in the mines, was subsequently employed on the surface and was slowly developed until it finally called for the locomotive, which had run in the roadway before going over to the railway. The author mentions the principal designs which preceded the real locomotive, that of George Stephenson. Turning to the foundation of the Belgian railway system, he mentions the political and economic circumstances which led to the idea of a railway and how, after lively discussions, the scheme was altered into a system of lines the first section of which was opened to traffic on the 5th May 1835. This historical review is illustrated by a happily selected collection of engravings, as too are the other parts of the paper.

The contrast in turning from the original stock to the modern equipment is startling. The latter reflects the present-day needs : greater speed, lower cost, and improved services.

The description of the recent Belgian locomotives shows how the latest ideas and arrangement have been taken advantage of, and the remarkable results obtained both as regards economical operation and as to power.

The railcars, introduced to reduce the costs and provide more frequent train services, are classified according to their capacity and power, as well as to the type of engine and transmission. The various solutions of the problem arising from the particular features of the petrol- and diesel engines are analysed. The discussion on the conditions under which the various types should be used is already based on several years' actual experience.

The electrification of the Brussels-Antwerp line is dealt with in a special chapter which gives detailed information on the general organisation, rolling stock, choice of current and substations, contact lines, structures, daylight signalling, and first cost.

E. M.

[385. (02 (.4)]

VEREIN MITTELEUROPÄISCHER EISENBAHNVERWALTUNGEN. — **Stationsverzeichnis der Eisenbahnen Europas** (*früher Dr. Koch's Stationsverzeichnis*). **List of European railway stations** (formerly Dr. Koch's list of stations). — A volume (17 × 7 inches) of XXII + 1 048 pages. — 1935, Berlin, Wilmersdorf, Von Barthol & Co., publisher, Mehlitzstrasse, 3. (Price : 28 Rm.)

The 51st edition of the list of European railway stations published by the Union of Central European Railways, under the editorship of its General Secretary, Mr. *A. Nether*, follows the same plan as the jubilee edition, reviewed in the October 1934 *Bulletin*.

The stations are given in geographical order in the first part and alphabetically in the second, each station having a reference number indicating the railway system it is on.

Many alterations have been made as the result of the great changes in the organisation of the German State Railways Company and the increase in the capacity of the cranes and weighbridges. New lines have furthermore been built and others closed in Poland, Finland, the Netherlands, Norway and Portugal. The Stanislaw division in Poland has been abolished and the whole chapter on Russia has been modified on account of the creation of six new divisions.

The appendix on road transport, first printed in the previous edition, has been markedly extended. It also contains a geographical and alphabetical list. In order to make reference easy, the same reference number is given to the transfer stations and stations where the rail and road service make contact as those used in the list of stations (in parts I and II).

E. M.

[385. (093 (.43)]

Hundert Jahre Deutsche Eisenbahnen. — Jubiläumschrift zum Hundertjährigen Bestehen der Deutschen Eisenbahnen (*The hundred years of the German Railways : Souvenir of the German Railway Centenary*). — Published by the Reichsbahn Headquarters. — A volume (11 3/4 × 8 1/2 inches) of 544 pages, abundantly illustrated, with many inset plates and three large maps as appendices.

The German railways in their turn celebrated, in 1935, the hundreth anniversary of the first line opened to service, the Nürnberg-Fürth section having been put into operation on the 7th December, 1835.

The Deutsche Reichsbahn Headquarters published this book on this occasion and dedicated it to all railwaymen who spent their energies in the development of the German railways.

The work is very extensive and is

designed on a very broad plan, the matter in it being as abundant as varied. It may be said to be a complete history of the system, so fully are the methods used and the different features of railway working dealt with in the various chapters.

To give some idea of the book, we will describe briefly the subject of the principal divisions.

The book begins with a general historical account followed by particular studies.

In the first part entitled : *The history of the German railways, a contribution to the history of German unity,* the authors have dealt with two periods separately, the first to the end of the world war, and the second to the present day, during which latter period the Deutsche Reichsbahn was formed.

Special hommage is paid to many of the German railway pioneers, to whose lives and work a whole chapter is devoted. Frederic List heads the list, he having been one of the few men who at once recognised the significance and mission of the railways, and thereby foretold the political and social part they were to play in the future.

His pamphlet of 1833 remains famous, like the map it contains, showing how a Saxon railway system could be the basis of a general German railway system.

A great variety of subjects are dealt with in the particular studies, and obviously by specialists. To mention a few, the construction of the permanent way, rolling stock, operating (traffic and working), financial questions, staff, and legal matters. Each chapter forms a complete history starting from the original conceptions and progressing to the present-day methods, ideas, and practices.

Although the professional railwayman is warned in the preface that the book will not satisfy his curiosity if he wishes to study the latest innovations, the most up to date equipment is nonetheless dealt with on broad lines and the principles described.

For example, in describing safety equipment, automatic train control is described. In connection with the rolling stock, the whole locomotive standardisation programme is dealt with. In the chapter on staff matters, the changes in, and standardisation of, pay are described, and the bases determining the present rates are outlined.

The work is adorned by many engravings, such as portraits, documents, equipment, structures, landscapes, ceremonies, uniforms, and picturesque scenes. There is also a series of humorous drawings.

Three good coloured appended maps show the German railways in 1885, 1914, and 1935.

E. M.

[656.212.5 (73) & 656.259 (.73)]

ASSOCIATION OF AMERICAN RAILROADS (A. A. R.), SIGNAL SECTION. — **American Railway Signaling Principles and Practices.** — Chapter XXI : **Hump Yard Systems.** — A pamphlet (8 × 6 inches)) of 68 + 22 pages, illustrated. — Published by the Signal Section of the A. A. R., 30, Vesey Street, New York, N. Y. — [Price : 35 cents (25 cents to members of the A. A. R. and railway employees). The cost of the collection of the 20 chapters issued is 6.35 and 4.35 dollars respectively. Holders to take 13 chapters : 1 dollar.]

The Signal Section of the Association of American Railroads has continued its series of educative publications by issuing this pamphlet on shunting yard equipment.

The equipment dealt with consists of point operating mechanisms and rail brakes (car retarders) worked from a central control tower.

Point operation mechanisms dealt with

include the electro-pneumatic with cylinders and valves at the points, and push button control machines. Track occupation indicators show the state of the tracks and if desired can interlock the controls. When all-electric operation is used, a control circuit preventing an occupied point from being moved is provided.

The car retarders or rail brakes used in America are of the type derived from the Hannauer retarder tested in 1923 at Gibson, Ind., on the New York Central Railroad, and named after the Vice-President, Mr. Hannauer, one of the two inventors, the other being Mr. E. M. Wilcox, Master Car Builder, of the Indiana Harbour Belt Railroad. In America, they are operated by electric motors or compressors and cylinders in conjunction with electro-pneumatic valves. When first introduced the track layout was altered as little as possible so that a good many sets of equipment had to be installed. Subsequently the tracks were brought together in groups of six, one rail brake being used in advance of each group.

A description is given of various types of apparatus. The drawings give the layout of the shunting sidings and explain the construction and operation of the appliances themselves and of the electrical motor or air cylinder. The diagrams of the circuits show the path taken by the motor and control currents and explains how the different degrees of braking are obtained. The control gear is shown in the photographs.

The skate machines are used as standbys.

Information is also given on signalling and on means of communication. The recommended signal code has five indications corresponding to three degrees of speed.

In some shunting yards, heated oil is put in the axle boxes in bad winters prior to the vehicles running over the humps.

E. M.

[625. 215]

LIECHTY (Roman), Engineer. — **Messungen über die Spurführung bogenlaüfiger Eisenbahn-Fahrzeuge** (*Tests of the running of railway vehicles with radial axles*). — Three volumes (8 1/4 × 11 1/2 inches), one of 30 pages of text including 18 figures, and two of diagrams. — 1936, Berne. Published by the Author, Weststrasse, 24. [Price : 15 fr. (Swiss currency.)]

We have already called our readers' attention to Mr. Liechty's book « Das Bogenläufige Eisenbahnfahrzeug » (The railway vehicle and its ability to negotiate curves) (*Bulletin* of June 1935). The theories developed therein are completed in the new pamphlets published by Mr. Liechty, giving detailed reports of the experiments carried out with some of the vehicles with radial axles previously described. These trials were carried out in collaboration with the St. Gall-Gais-Appenzell Electric Railway, the Frauenfeld-Wil Railway, the Basle tramways, and the Berne-Lötschberg-Simplon Railway.

The main object of the tests was to ascertain the position of the wheels relatively to the rails and therefrom deduce the factors for calculating the friction between the flange and the rail, and the position of equilibrium of the axles.

Pamphlet I gives particulars of the tests and pamphlets II and III reproduce the whole of the diagrams obtained during the tests, in particular in terms of the distances travelled over, the variations in the gauge, the angle between the flange and the rail, displacement of the axles relatively to the frame, deflection of the springs, etc...

Pamphlet I containing the text des-

cribes the measuring instruments used; in principle they are not unlike those used by the Paris-Orléans Railway Company in its investigations into the hunting of vehicles, and described by Mr. Mauzin in the *Revue Générale des Chemins de fer* of January, 1933. The author then deals with the tests on wagons with 3 radial axles, on the Klose and S. L. M. systems, on four-wheeled wagons, and on a Berne-Lötschberg-Simplon Railway railcar fitted with the Liechty gear.

The author then states the conclusions to be drawn from these investigations as regards laying the track, and designing the vehicles. He adds that the question is to be investigated much more fully by further tests.

A bibliographical supplement giving the studies or articles recently published on the subject completes the work which is a most valuable contribution to the running of railway vehicles through curves.

A. C.

[385. (09.3 (.493)]

BELGIAN NATIONAL LIGHT RAILWAYS COMPANY. — **Fiftieth Anniversary, 1884-1934.** — One vol. (10 5/8 × 7 1/2 inches), of 116 pages, with many illustrations, and inset plates. — 1934, Brussels; Goemaere, publisher, 21, rue de la Limite.

The Belgian light railway system is probably unique in the world. The length of the lines operated by the National Light Railways Company, all narrow (metre) gauge, is almost the same as the standard gauge, i.e. 4 743 km. (2 947 miles) or 15.53 miles per 100 square miles. The concessions granted are for 5 277 km. (3 279 miles).

The remarkable work indicated by these figures has all been completed in half a century. The Belgian Light Railways began operations under the law of the 28th May 1884, slightly amended in 1885, and have never since ceased from increasing their system of lines. Ten years from the start, 1 249 km. (776 miles) of lines were in working.

The fiftieth anniversary of the Company, which has successfully guided the light railways through many difficulties to their present state of perfection, was marked by two ceremonies. On the 12th June 1934 a formal meeting was held in the Palais des Académies, at which H. M. the King of the Belgians was present. M. Léon Jacobs, the General Manager of the Company, outlined the history of the system. Three months later, a memerial was unveiled at the Company's Headquarters, and the authoritative speeches referred to the most notable events in the still recent history of the Belgian light railways.

The Company printed the text of the speeches, together with an account of the celebrations. The attractive volume containing them gives as a foreword a note entitled : *History of the Belgian National Light Railways Company (1884 to 1934).*

This interesting note is of particular importance in view of the present-day conditions.

The birth of the Belgian light railway system is described. The author analyses the economic conditions when they were authorised, the function their founders ascribed to them, the main features of the 1884 law, the special and original nature of the Company and its financial and administrative organisation, etc., etc.

Further on he describes how the narrow-gauge lines satisfied the hopes placed in them, and how agriculture, trade, and industry, the working classes and indirectly the public authorities benefited by them. The reader will also be able to see the vicissitudes met by

the Company and the methods by which the services have been improved and modernised.

Amongst measures taken to improve the light railways must be mentioned electrification and railcars.

The first electrified lines were opened on the 1st October 1894, and in 1913 the length had grown to 410 km. (255 miles). After the world war, when the economic crisis and road competition had to be faced, the Company extended its electrification in order to revive the passenger traffic on many of the lines threatened.

On other less favoured lines the railcar offered a solution. A special type designed by the Company has come into wide use on most of the lines on which steam traction continued to be used for working passenger traffic.

The note also deals with road transport, with the steps taken in the matter, and the great part the Company played in the organisation of omnibus services.

The Belgian transport problem is discussed and the position of the light railways and the functions falling on them considered.

The author has not failed to pay a tribute to the founders of the Company and those who contributed to the success of the undertaking, with a fine series of photographs recalling the features of most of them.

The illustrations also include several characteristic types of rolling stock and a number of graphs showing the growth of the system, the evolution of the traffic, and the extent to which the different traction methods have been resorted to.

E. M.

[347. 763.4 (.44)]

POLLACZEC (Dr. Gustav). — **Grundzüge des Französischen Eisenbahn-Frachtrechts** (*Principles of the French law on goods transport*). — One vol. (9 × 6 inches) of 112 pages. — 1935, Vienna; Publications of the Allgemeiner Tarif-Anzeiger (General rates tables) : A. Freud, 10, Biberstrasse. (Price 12 schellings.)

Any study of the French law on goods transport is made difficult by the complexity of the subject and the variety of Acts, sometimes incomplete, which have to be examined. A knowledge of this law is useful, however, for the foreigners, especially those who have to use the international convention on goods transport which frequently refers to the laws in force in the countries party thereto.

The author has put before us a precise summary of the French laws, decrees, rates, etc... relating to goods transport.

After briefly touching on the building up of the railway systems, the author indicates the foundations of the law on transport. He deals with the meaning and classification of the rates, with the right of initiating rates and approving them, with their publication, and the legal aspect.

The next chapters deal with the obligation to accept goods offered for carriage, waybills, and other documents, and the calculation and payment of the rates and other charges.

The transport contract is next considered and the author shows how it is carried out, and the alterations it may undergo. He then examines the responsibility of the railway and any litigation which may result.

In the early part of his book, the author mentions a number of publications to which he frequently refers the reader, for the texts themselves and for decisions binding in law.

E. M.

[621. 43]

NICOLET (V.), Assistant Chief Engineer, French State Railways, and President of the French Main-Line Railways' Railcar Commission. — **Les autorails. Doctrine générale de leur emploi et de leur construction** (*Railcars. General principles governing their design and use*). — A pamphlet (10 5/8 × 7 1/8 inches) of 38 pages, with 26 figures. — 1935, Paris; Published by the journal *Le Génie Civil*, 5, rue Jules Lefebvre.

The *Génie Civil* has just published, as a fully illustrated pamphlet, the very valuable paper read by M. V. Nicolet, Assistant Chief Engineer of the French State Railways and President of the French Main Line Railways' Railcar Commission, at the Brussels exhibition on the 13th September 1935, before the French Section, on the general theory of the use of railcars and their construction.

After reviewing the vital need for a quick and radical alteration in railway transport in view of road and air competition, the author shows how the road motor has suggested a new tool, the railcar, bringing to the railway the good features of the road vehicle, and how the development of this new method of transport in France has helped to give the builders the same freedom they have when building road vehicles, whilst complying, of course, with the railway regulations in force.

M. Nicolet then analyses the new operating principles involved in railcar operation. The railcars were intended in the beginning to replace steam traction on branch lines; now the railcar is used not only for working such lines but also as pick-up trains between the stopping places of the main-line express trains. They are also used for the through or stopping trains on cross-country lines with few trains and also for express services on the main lines. This extended use raises certain problems in connection with rushes of passengers, peak traffics, variable demands, and maximum capacity of the new method. The author examines and discusses them before dealing with the French railcars, i.e. with technical questions affecting their design and construction, such as lightening the vehicle, high power/weight ratio, use of pneumatic tyres, transmission gears, petrol, gas oil and steam engines, brakes.

In his conclusions, the author sees the day in the near future when, excepting electrically operated suburban services, night trains and certain day trains running at hours when a large number of seats are needed, all other passenger traffic and even certain parcels trains will be worked in France by railcars.

The results so far are most encouraging as regards increasing the numbers of passengers and reducing the working costs.

The author ends by expressing his conviction that the railcar will be improved quickly both as regards design and operation and that the public will return to the railway in increasing numbers and end by appreciating at their true value the speed, comfort and safety of rail working as compared with the road.

A. C.